SURVEY & GEOMATICS STANDARDS

Utah Department of Transportation

3/17/2017

This page intentionally left blank.

TABLE OF CONTENTS

REVISIONS

March 2017 Revisions:

- Chapter 5-Updated Figure 5-2 Survey Control Sheet Example
- Chapter 6-Added DTM DENSITY & CLASSIFICATION section, typographic clarification, and deliverables.
- Chapter 7-Updated staking tolerances, typographical clarifications, revision to structure control network, and suggestion for contractor and surveyor meeting.
- Chapter 12-Added new requirements for UAS Flights
- Chapter 13-Added information for Right of Way Design Manual
- Chapter 15-Creation of utility survey chapter and relocated SUE under this section.

INTRODUCTION

The UDOT Survey and Geomatics Standards establishes minimum standards for performing surveying and geomatics for the Department. These standards apply to all personnel who perform surveying and geomatics for the Department (Department employees, consultants, and contractors).

These standards will help the Department achieve its goal of implementing full 3D design and 3D engineered models.

Information in this document is excerpted and adapted from multiple public documents as listed in the references in the appendix.

CHAPTER 1: GENERAL REQUIREMENTS

Follow proper surveying methods and procedures according to this document.

Perform quality control on all surveying for the Department. The quality control process includes reviews of ground control surveys, flight alignments, photographic quality, stereo compilation, map accuracy, and map completeness. The degree of quality control required is governed by this document unless the contract specifications specify otherwise based on the end functional use of the product.

Comply with Federal, State, and local laws.

Safeguard all endangered species, avoid harming vegetation, do not disrupt wildlife activities, and do not damage items of historic or archeological interest. Do not remove from the site historic or archaeological artifacts.

Report discoveries of historic or archeological artifacts or sites to the Department's Project Manager.

Perform all CADD work in a georeferenced MicroStation file and according to *UDOT CADD Standards*.

The official units of the Department are US Survey Feet.

PERMIT & PERMISSIONS

Obtain an Encroachment permit before performing work on Department rights of way. More information can be obtained by visiting the Statewide Permits office or by applying online.

Obtain permission from other public or private parties before entering their land in accordance with Utah State Code 78B-6-506 Rights of entry for survey and location.

The following is a list of potential contacts needed for the above requirement:

Agency	Information Required
Federal Agencies/Bureau of Land Management/Forest Service/National Park Service/Bureau of Reclamation/U.S. Geological Survey/Department of Defense/Bureau of Indian Affairs	Permission to Enter/ Survey Markers
UDOT Permits Officer	Encroachment
UDOT Region ROW Engineer	Survey Control
Local Governments	Permission to Enter/ Survey Control
State Land Board	Permission to Enter
School and Institutional Trust Land Administration (SITLA)	Permission to Enter
Indian Nations	Permission to Enter
Railroads	Permission to Enter
Private Property Owners	Permission to Enter

CHAPTER 2: SAFETY

INTRODUCTION

Each year the Department averages more than 100 work zones on state highways alone. In addition, Utah averages five fatalities within those work zones. These accidents occur in two areas; encroachments into the work zone, and accidents outside the work zone but influenced by the zone.

Safety is of utmost importance in reaching the Department's goal of Zero Fatalities. All safety procedures outlined in UDOT Safety and Health Manual, UDOT MUTCD, and other state and federal laws and regulations shall be followed at all times in the performance of assigned, contracted, and permitted operations within areas under the jurisdiction of the Utah Department of Transportation.

This chapter of the Surveys Manual is intended to provide safe operating procedures, guidelines, and practices, specific to Department surveying operations; and supplement the policies, procedures, and practices set forth in the UDOT Safety and Health Manual and the Utah Strategic Highway Safety Plan.
http://www.udot.utah.gov/main/f?p=100:pg::::1:T,V:1690
http://ut.zerofatalities.com/downloads/SHSP-ZeroFatalities.pdf

The UDOT Safety and Health Manual provides detailed instructions for managers, supervisors, and employees to assist them in their individual efforts to conduct Department business in a safe and healthy manner consistent with current law, rule, and technology. The Utah Strategic Highway Safety Plan is a culmination of the joint efforts of all traffic safety organizations in Utah and sets the vision, goals, and areas of focus for our future collective safety efforts. Every supervisor and lead worker should have a copy of the UDOT Safety and Health Manual and the Utah Strategic Highway Safety Plan available for use.

THE UDOT SAFETY AND HEALTH POLICY STATEMENT

In 2003 the Utah Safety Leadership Executive Committee set a goal to create a comprehensive, integrated plan aimed at reducing serious injuries and fatalities, with the ultimate goal of Zero Fatalities on Utah's roads. The loss of one life is too many. When you ask someone how many of their loved ones they want to lose on the road this year, everyone has the same answer: zero. The goal of the Department is to achieve zero accidents and injuries through, regular monitoring of work practices and the enforcement of safety standards. The Department partners with Contractors, and Consultants to provide a safety plan focused on protecting the health and safety of its employees while ensuring they have a safe and healthful place to work.

UDOT SAFE SURVEYING PRACTICES

The UDOT Code of Safe Surveying Practices Figure 2-1 was developed to summarize the "Safety Chapter" of this Manual. The Code should be posted as a reminder of the importance of safety.

FIGURE 2-1 -UDOT CODE OF SAFE SURVEYING PRACTICES

Distribution

All Survey employees shall have a ready access to this code.

Philosophy

No survey project is important or urgent enough to warrant compromising safe surveying practices.

Responsibilities

Individuals:

All field personnel shall have a practical working knowledge of this Code, the UDOT Safety and Health Manual, and this section of the Surveys Manual.

Employees are responsible to:

Do everything reasonably necessary to protect life, safety, and the health of themselves, other employees, and the public.

Comply with all occupational safety and health policies, procedures, laws, rules, and regulations.

Promptly report injuries, illness, accidents, and unsafe conditions, tools, and equipment to their supervisor or leadworker "in charge."

Report to work mentally and physically capable of performing all their assigned duties without jeopardizing the safety and health of themselves, other employees, or the public. This means employees must be free from the effects of medication, controlled substances, alcohol, or the complications arising from illness or injury which might impair judgment or the ability to perform their work.

Supervisors or leadworkers "in charge" are responsible for:

Monitoring safety conditions and employee performance.

Instructing employees about safety policies and practices affecting them.

Prohibiting employees from working when they appear to be unable to perform their duties and there is concern about the safety of the employee or others.

Designating a responsible person-in-charge when they are away from the workplace.

Planning for Safety

Safety shall be given top priority in the planning of all surveys.

Factors considered when planning a survey shall include:

The safest time of the day that the survey can be accomplished.

The optimum number of personnel to accomplish the survey safely.

The assignment of specially trained and qualified personnel to the more hazardous jobs.

Using surveying methods that minimize employee exposure to traffic.

Personal Clothing Requirements

Each employee must provide and wear their own clothing and footwear that will provide adequate protection for the assigned task.

Personal Protective Equipment

Hard Hats:

State-issued hard hats must be worn while exposed to vehicular and equipment traffic, falling or flying material, and other similar hazards, and shall also be worn when employees are within the right of way of a traveled road or on a construction site.

Warning Garments:

Fluorescent Orange or yellow-green color vests, shirts, or other warning garments meeting ANSI/ISEA 107-2010 Class II or III specifications shall be worn when exposed to vehicular or equipment traffic and when working within the right of way of a traveled road or on a construction site. Never wear red within Railroad R/W.

Eye Protection:

Safety glasses, goggles, or face shields shall be worn when working near traffic or using drilling and driving machines and tolls, or encountering falling or airborne and windblown material, or other similar hazards.

Ear Protection:

Ear plugs or muffs shall be worn when working around hazards affecting the ear or when noise levels may cause hearing loss. As a general rule, if you cannot carry on a conversation without shouting, the noise level requires hearing protection.

Other:

Special safety equipment such as steel-toed boot covers, etc. shall be provided and shall be used as required and directed.

Safety Meeting

Tailgate meetings shall be held by each survey party at least once every ten working days. Meetings shall be held as required to prepare for imminent and especially potent hazards. Such hazards shall include, but not be limited to, power lines, poisonous plants, snakes, insects, animal hazards, mountainous terrain, high-fire-hazard areas, traffic, heavy equipment, water, exposure, and high temperature.

Safety Training

Employees shall be provided all mandatory safety training. Specialty training, such as chain saw operation, shall be provided as required.

Vehicular Traffic

Work, no matter how short the duration, must not be performed on or adjacent to the traveled way without proper protection. This includes proper warning garments, signs, flaggers, lookouts, and/or lane closures, as required to work safely.

Tools and Equipment

Use only the proper tools, in the proper condition, for each job. Do not operate equipment unless you have received training in its use.

First Aid Requirements

Each member of a field survey party or working group shall receive first aid training at least once every two years. Each survey party vehicle shall be equipped with an approved 16-unit or larger, first aid kit, First Aid Manual, and fire extinguisher.

Vehicle Operation

All operators of State-owned vehicles must be trained in defensive driver training once every four years. Each operator must drive defensively and observe all applicable traffic laws.

Operational Precautions

Do not enter ditches, trenches, conduits, or confined spaces until you are certain it is safe to do so.

Suspend operations when unsafe conditions or uncontrollable hazards develop. Resume work only when safe conditions have been restored.

When working in an unfamiliar environment, check with others about safe procedures.

Be especially careful when working at night, on steep slopes, or near power lines.

SAFETY RESPONSIBILITIES

For a description of Region and Contractor safety responsibilities see the UDOT Safety and Health Manual Chapter 2, “Responsibilities”.

INDIVIDUAL RESPONSIBILITIES

Each employee is responsible to:

- Have a practical working knowledge of, and adhere to, the provisions of the Code of Safe Surveying Practices and this Chapter of the Surveys Manual and the UDOT Safety and Health Manual;
- Be alert for possible unsafe conditions and/or unsafe acts. Report unsafe conditions and/or acts to the supervisor or lead worker “in charge;”
- Use equipment properly and carefully, and follow all health and safety policies, procedures, and work practices, as directed by his/her supervisor, and ask for instructions or assistance if unable to understand the assigned task;
- Promptly report all incidents, accidents and personal injuries to their supervisor after rendering or finding aid for injured persons;
- Report to work mentally and physically capable to perform all assigned duties without jeopardizing the health and safety of themselves, other employees, or the public;
- Report for work properly dressed to protect themselves from exposure to conditions found on the work site. Employees will dress appropriately for their specific duties in accordance with the Dress Code for Department Employees UDOT 05-32. Garments that expose upper body parts (midriff and shoulders) and bare legs are prohibited. Employees shall wear appropriate footwear for the assigned task and work area.

PERSONAL PROTECTIVE EQUIPMENT

Each employee is furnished personal protective equipment which shall be consistently used. Specifications for personal protective equipment shall comply with all state and federal laws.
Hard Hat: Employees are responsible for wearing hard hats (ANSI Type I, Class E Approved) during any work activity that may expose them to a head injury. The hard hat must be worn when working within any street or highway right of way or on a construction site.
Safety Vest: High visibility apparel (vest, shirt, or jacket) of fluorescent orange, or yellow-green color that meet the specifications of ANSI Class 2 must be worn whenever working within any highway right-of-way or within the limits of a construction project. Class III apparel is required for flaggers and all night work. Orange is the only approved color for vests or shirts when working on railroad rights of way.

When conditions warrant the following personal protective equipment should be provided to employees:

- Safety glasses (see note below)
- Safety Goggles
- Dust masks
- Gloves
- Hearing protection
- Chaps
- Rainwear
- High visibility apparel

Note: See the UDOT Safety and Health Manual, Chapter 7.5 Personal Protective Equipment Details.

PARTY CHIEF RESPONSIBILITIES

A designated Party Chief, whether a supervisor or a lead worker, is responsible for the work methods and safety practices of the survey party. It is the Party Chief's responsibility to ensure that all safety rules and procedures are followed and that all work is performed safely. The Party Chief must ensure the use of the safest possible method for each operation. This responsibility may not be delegated.

The following summarize common responsibilities of the Party Chief:

- Ensure that a copy of the Code of Safe Surveying Practices, the UDOT Safety and Health Manual, and the UDOT Surveys Manual is always available to employees.
- Give safety first priority in planning each survey. When first reporting to a new job site, it is the responsibility of the Party Chief to reconnoiter the entire site, taking note of all potential hazards such as power lines, steep inclines, hazardous traffic areas, abandoned mines, animals, or other safety concerns. This information will be discussed with the field crew as part of the tailgate safety meeting conducted for new job sites (see Section 2.4)

- Before starting work, inspect all traffic controls for conformance to MUTCD. Continue to monitor conditions to ensure that controls are adequate for any change in conditions.
- Cease work and notify the field supervisor immediately if any field conditions are such that safety is jeopardized.
- Train and provide lookouts whenever necessary.
- Train and provide flaggers whenever necessary.
- Utilize attenuator trucks or other protective vehicles whenever appropriate.
- When possible avoid assigning party members to independent tasks that isolate them from the other party personnel. Try to have each member working with a buddy. (This is especially important in high-hazard areas, such as along roads, and in remote desert and mountain areas.)
- Ensure that each subordinate possesses the required personal protective equipment and uses the equipment as required.
- Train new employees to safely perform required work tasks before assigning them to work independently.
- Ensure that tools are used and stored safely.
- Do not allow employees to work if they refuse to work safely. Refer the matter to your supervisor.
- Report all violent acts, threats of physical violence, verbal abuse, property damage, security hazards, and other inappropriate activities to the field supervisor or security guard.
- Conduct a tailgate safety meeting with party members at least once every ten working days, or as needed. See Section 2.4. Report and document all occupational injuries and illnesses.
- Designate a responsible person-in-charge when party chief is away from the workplace.

FIELD AND OFFICE SUPERVISOR RESPONSIBILITIES

Field and office supervisors may be first or second line supervisors. Field supervisors generally supervise more than one field party.

Supervisors are to conduct Department business in the safest possible manner consistent with Department policies, procedures, and work practices. This includes:

- Enforce all health and safety laws, rules, and policies, and initiate corrective action for employees who violate health and safety laws, rules, and policies.
- Ensuring that all employees receive required first aid and defensive driving training, as well as any required specific training for hazardous tasks such as operating a chainsaw.
- Ensuring that all employees receive Safety Training for special circumstances including construction surveys on superstructures. All field personnel shall be certified to a minimum 10-hour OSHA safety course.
- Ensuring that employee safety and health issues are discussed and assessed annually at the time of conducting the Individual Performance Plan and Evaluation report and when employee probationary reports are issued.

- Scheduling all required safety meetings. Supervisors should provide sample tailgate meeting topics and outlines to party chiefs and utilize regular staff meetings to disseminate information on accident prevention and on new safety policies and devises.
- Periodically inspecting field and office work sites to identify, document, and eliminate hazards that might cause injury or illness.
- Ensuring that each field crew have access to:
    - UDOT Survey and Geomatics Manual
    - UDOT Safety and Health Manual
    - Maintenance Manual – Protection of Workers
    - Manual on Uniform Traffic Control Devices
- When assigning field crews to projects, field supervisors are responsible for:
    - Approving work within six feet of moving traffic.
    - Obtaining an approved traffic control plan, if necessary, and providing a copy to the party chief.
    - Approving all surveys without traffic controls.
- Supervisors are responsible to report and document occupational injuries and illnesses, and arrange for appropriate workers' compensation benefits to employees who are injured or contract an illness arising out of their employment. For details on reports, see UDOT Safety and Health Manual, Chapter 4, "Reporting Accidents, Incidents, and occupational Injuries and Illnesses."
- When assigning field crews to projects or sending office personal on field trips, consider:
    - The experience of personnel in undertaking hazardous tasks.
    - Possible health problems for specific employees (such as poison oak allergies).
    - Traffic hazards (plan for any controls that are needed).
    - Unusual hazards associated with the work.
- Field/office supervisors are responsible for new employee orientation, as follows:
    - Provide new employees a copy of the Code of Safe Surveying Practices and make available a copy of the UDOT Safety and Health Manual and the Survey and Geomatics Standards Manual, require that new employees read each document.
    - Show the employee – List of facilities that are approved for treating industrial injuries.
    - Ensure that the employees assigned to the field are scheduled for first aid training as soon as available or within the first three months of their assignment if possible and at least once every two years thereafter.
    - Describe hazards that are likely to be encountered in the employee's first assignments and the protective measures to be used.
    - Brief the employee on:
        - Medical care available throughout the State.
        - State Compensation Insurance Fund benefits.
        - The role of the District Accident Prevention Committee.
        - The supervisory accident investigation process and its purpose in preventing accidents.
        - Accident and injury reporting and their purposes.
        - The right to refuse to perform tasks that are dangerous or hazardous.
        - Responsibilities in case of personal and motor vehicle accidents.

SAFETY MEETINGS

POLICY

Supervisors shall schedule, conduct, and document safety meetings with their employees to discuss occupational safety and health issues. Document all safety meetings with the Job Safety Analysis (JSA) Worksheet, Appendix E – UDOT Safety and Health Manual.

Tailgate Safety Meetings for Field Personnel

At least once every ten working days, or as necessary for special circumstances, each Party Chief shall conduct a tailgate safety meeting. Special circumstances include: reporting to a new job site, a change in crewmembers, or a change in the work environment. The tailgate safety meeting should focus on safety considerations for the survey party’s current assignment.

Office Personnel Safety Meetings

Meetings for office personnel to discuss safety or health concerns must be held at least once every three months.

CONSTRUCTION SURVEYING OPERATIONS

The Resident Engineer is responsible for safety on Department construction sites. Notify the Resident Engineer that you will be working on the project and of any unsafe observed operations or conditions. Before beginning a construction survey, determine potential hazards that might arise from the natural environment, the public, and the contractor’s operations. For project conditions not covered by the surveying manual, use the construction code of safe practices for the project. Plan the survey accordingly.
During the course of the work, observe the following safety guidelines:

- The Contractors traffic patterns, especially hauling operations, are governed by optimal production rather than typical rules of the road, don’t assume anything.
- Be extremely cautious around heavy and fast-moving equipment, especially on haul roads and around equipment with limited driver visibility.
- Do not rely on the operator’s visibility, judgment, or ability, Make eye contact with the operator and confirm it is safe before walking in front of or behind any piece of equipment.
- Suspend survey operations when uncontrollable hazards develop. Resume work only when safe working conditions have been restored.

SURVEYING NEAR TRAFFIC

Working in, near, and around traffic is an inevitable part of transportation land surveying work. The SURVEY CREW (MUTCD W12-6) sign should be used to warn of surveying crews working in or adjacent to the roadway. Field crews need to take the following precautions to ensure this work is performed as safely as possible.

GENERAL PROCEDURES

Use the following general safety procedures when working in or around traffic:

- **Required "Free Space":** Maintain at least six feet of space between moving traffic and your work area. This includes work on shoulders as well as on the traveled way. Survey at the maximum space possible between moving traffic and your work area. Any surveying that requires working within six feet of moving traffic must be approved by the Field Supervisor or the Survey Manager.
- **Face Traffic:** Whenever feasible, each employee must face moving traffic at all times. If it is not possible to face traffic, a lookout should be used.
- **Move Deliberately:** Do not make sudden movements that might confuse a motorist and cause and accident.
- **Signal Cautiously:** Whenever feasible, use radio communication. Carefully and deliberately use surveying hand signals so they will not startle or confuse motorist or be mistaken for a flagger's direction.
- **Avoid Interrupting Traffic Flow:** Minimize crossing traffic lanes and never attempt to run across traffic lanes.
- **Physical Barriers:** Whenever feasible, place a barrier vehicle or a shadow vehicle between moving traffic and workers. See Figure 2-2.
- **Distractions to Motorists:** Minimize working near moving traffic, especially on high-speed roads, when the motorists' attention may be distracted by other ongoing activities, such as vehicular accidents, maintenance activities, and construction operations; or distracting objects on or along the highway. Do not work along streets or highways within 2000 feet of such activities or objects.

LOOKOUTS

While working on foot on or near the traveled way, workers should normally be protected by barrier vehicles, guardrail, or other physical means. Where the absence of such physical protection exposes workers on foot to errant vehicles, a person shall be assigned as a lookout. A lookout is an employee whose only duty is to provide immediate warning to coworkers of vehicles or equipment that have become imminent hazards to their safety. The lookout shall not try in any way to direct traffic. A lookout is used only to warn of impending traffic hazards, not direct or control it.

When work occurs within any railroad right of way, railroad provided or approved lookout and permit to enter is required.

- Lookouts are required when all of the following conditions exist:
    - Work occurs on a roadway with a posted speed of 55 mph or more.
    - Workers are without physical protection (barrier vehicle, concrete barrier, natural or man-made terrain features, etc.).
    - Working on foot within 30 feet of moving traffic.

- Lookouts should be considered whenever:
  - Working without traffic control on streets and highways.
  - Working within 25 feet of the centerline of an actively-used railroad track outside of a railroad right of way.
  - Where there are conflicting or multiple vehicular and equipment movements.
  - In areas with restricted sight distances.

Lookouts must be in constant communication with the employee under their protection. If restricted sight distance or other factors preclude verbal communication, use a radio. Lookouts should be stationed where they can observe traffic sufficiently in advance of the workers to warn them of approaching danger by out of control vehicles. Use audible warning devices such as horns or whistles. In some cases, more than one lookout may be necessary. When it appears that a vehicle or some equipment has become a threat to personnel, the lookout will immediately and repeatedly use the word “scramble,” or activate a warning device.

FLAGGERS

A flagger is a trained person who gives motorists, pedestrians, and cyclists exact instructions, enabling them to move through temporary traffic control zones safely. Flaggers should be carefully chosen because they are responsible for public safety and make the greatest number of public contacts of all highway workers. Because of their importance and responsibility, flaggers should be rotated and relieved periodically to maintain alertness.

Flaggers must be used any time two-way traffic must share the same lane because of work in the other lane. Generally, flaggers should not be used along freeways.
Flaggers shall be trained in flagging procedures and use the proper equipment and safety garments outlined in the Manual on Uniform Traffic Control devices, Section 6, “Temporary Traffic Control.” A copy of the MUTCD should be available to each survey party.

PROTECTIVE VEHICLES

Protective Vehicles can be especially important at sites, such as instrument set-ups, where surveyors might be located for an extended period of time. There are two types of protective vehicles:

Barrier Vehicle: A vehicle, usually unoccupied, which is parked between the oncoming traffic and stationary work site.

Shadow Vehicle: A vehicle with an attenuator which follows a survey operation moving in the direction of traffic.

Position protective vehicles so they are effective barriers to the traffic. Keep a protective vehicle close enough to employees to give actual physical protection but not so close that it is a hazard to employees.

AMBER WARNING LIGHTS AND EMERGENCY FLASHERS

- Use amber warning lights, emergency flashers, or both as needed:
  - To alert traffic of workers on foot or operations near the traveled way.
  - When moving into or out of traffic.
  - When parked outside of a lane closure within 6 feet of traffic.
- Do not use the amber lights when driving at normal highway speeds, when parked in an established lane closure, or when parked over 6 feet from traffic, unless circumstances warrant usage. Misuse and overuse of warning lights seriously reduces their effectiveness. When working during the hours of darkness, use the amber lights with discretion. Do not blind or distract traffic needlessly. At times, the vehicle's emergency flashers may be more effective.

TEMPORARY TRAFFIC CONTROL

Temporary traffic controls are used to establish a "working area-of-protection" for employees. Methods of temporary traffic control include use of: a) portable warning/control devices, b) prescribed procedures (see below), and c) personnel such as flaggers and lookouts. Traffic movement should be disrupted as little as possible by traffic controls. Optimum safety can be achieved most effectively through controlling the activities of surveyors rather than restricting vehicular movements.

PROCEDURES

- Do not undertake any form of temporary traffic control without consulting and following the directives of the MUTCD.
- Lane closures should only be undertaken with the approval of the Region Traffic Engineer.
- The protection of employees and the public shall be the primary consideration when temporary traffic control measures are used.
- All reasonable measures shall be used to avoid interference with vehicular movement. Lane and shoulder closures shall not be considered until other alternatives have been evaluated for employee protection.
- Minimize the time temporary control devices are used. Employee breaks should be scheduled so that temporary control devices are utilized for the entire period they are in place.
- The party chief is responsible for inspecting and monitoring traffic controls set by surveyors or others. If controls are inadequate or conditions change, surveying activities shall be halted until a safe condition is established.
- Except for special surveys or because of lack of reasonable daylight alternatives, surveys on or adjacent to roads shall be done only during full daylight hours.
- In general, limit the length of a work area to 0.5 mile. When the scope of the survey is longer than 0.5 mile, divide the survey into lengths of 0.5 mile or less. When using lane

or shoulder closures, limit the total closure length to an area that can be surveyed during an uninterrupted period of work.

PLANNING

- When planning a surveying project that requires temporary traffic controls, be sure to:
- Use standard traffic control layouts shown in MUTCD.
- Use surveying methods that minimize exposure to traffic hazards.
- Consider factors that will affect traffic hazards and implement temporary traffic controls to minimize the hazards. Some factors to consider are:
    - Prevailing traffic speed.
    - Peak traffic hours.
    - Motorists' sight distances.
    - Effect of unusual survey activities on traffic.
    - Pavement Conditions – wet, frosty, etc.
    - Special conditions and events, such as school hours and large public gatherings.
    - Inform District Traffic Operations and obtain necessary approvals, if any survey activity is going to significantly affect the normal flow of traffic for 20 minutes or longer.
    - Observe local district/region policies and procedures regarding traffic controls.
    - Coordinate traffic control activities with Maintenance, Construction and UHP, as appropriate.
    - Assign adequate personnel to survey parties to meet special safety needs, such as flaggers or lookouts.

SURVEYING WITHOUT TRAFFIC CONTROLS

Even when traffic is light, the closing of a lane or setting of other controls might be the most dangerous aspect of a survey. Under certain conditions some surveys can be undertaken safely without including the risk of establishing traffic control. Exposure and risk can be minimized without purposely affecting the flow of traffic. An example is determining elevations of edges and centerline of roadways. Short term surveying operations may be undertaken without traffic control if all of the following conditions exist:

- Approval of the Surveys Field Supervisor or Surveys manager.
- The traffic volume is light. This means that surveyors can walk from the shoulder to the site on the traveled way, perform their duties, and walk back to the shoulder without interfering with traffic.
- Sight distance in each direction is at least 550 feet. When 550 feet of site distance is not available, one or more lookouts may be posted to extend visual coverage.
- Vehicles can be parked completely off the traveled way.

If all of the above conditions are met, the survey can be undertaken without traffic controls using ALL of the following methods:

- One surveyor shall be used as a lookout.
- All surveyors shall be off the traveled way when traffic passes.
- Surveyors shall face traffic whenever possible.
- Surveyors have a planned escape route.

YELLOW-STRIPE SURVEYS

The term “yellow-stripe” survey is used to designate those surveys along the centerlines, or lane stripes, of conventional roads. A yellow-stripe survey without a lane closure must be approved by the Field Supervisor or Surveys Manager. A yellow-stripe survey with a lane closure must be recommended by the Field Supervisor and approved by the Surveys Manager after consultation with the District Traffic Manager.

Yellow-Strip surveys must be performed during off-peak hours, Traffic control procedures for yellow-stripe surveys are described in the MUTCD. See Section 2.6-7, Surveying without Traffic Control,” to determine if conditions warrant a survey without traffic controls.

FIRST AID

First aid is defined as follows:
“The assistance provided the sick or injured before medical help is available but only with the express purpose of controlling the loss of blood, sustaining breathing, and reducing the effects of shock. Suitably trained personnel are highly recommended. Medical diagnosis, treatment, and provision of medicines or drugs (aspirin included) are not appropriate.”

The following are basic requirements that must be met to ensure adequate response to a situation requiring the use of first aid:

- All surveys field personnel shall be trained in first aid during the first three months of their assignment and at least every two years thereafter.
- Each survey vehicle and office shall be equipped with a 16-unit first aid kit.
- Each survey vehicle and office shall have a readily available copy of a current Red Cross First Aid Manual or equivalent.

ENVIRONMENTAL HAZARDS

WEATHER HAZARDS

When working in hot conditions, ensure adequate potable water, a minimum of 1 quart per person per hour of scheduled work, is available at the start of each shift. It is allowable to begin the shift with smaller quantities of water if there is an effective procedure for replenishment during the shift as needed to allow employees to drink one quart or more per hour. Ice does not constitute water.

When working in hot conditions, access for a period of no less than five minutes to an area with shade that is either open to the air or provided with ventilation or cooling shall be provided to employees suffering from heat illness or an employee believing a preventative recovery period is needed. Such access to shade shall be permitted at any time.

ANIMAL HAZARDS

During the normal course of land surveying it is common to encounter animals. Try not to startle or surprise an animal. Avoid contact with animals as much as possible.
Be familiar with the precautions concerning Snakes, insects, and other wild or domestic animals that one should practice.

Understand the first aid treatment for snake bites, insect bites, and other injuries that could be caused by wild or domestic animals.

Know the location of the nearest medical facilities where medical care is available and the quickest route there.

PLANT HAZARDS

During the normal course of land surveying it is common to encounter plants, some of which that can cause injury or allergic reaction. Learn how to identify these plants before going into the field, warn others on the crew when detected, and avoid contact as much as possible.

Medical authorities agree that avoidance is the best prevention for poison oak, grease wood (or creosote bush) and encilia in desert areas, and many native plants that have thorns and nettles (cacti, wild berries, thistles, roses, bougainvillea) that can give painful wounds.

Always be careful when walking through thick brush where it’s difficult to identify the next plant you will encounter.

Be familiar with the precautions concerning plant hazards that one should practice.
Understand the first aid treatment after exposure to hazardous plants.

Know the location of the nearest medical facilities where medical care is available and the quickest route there.

CHAPTER 3: SURVEY DATUM & COORDINATE SYSTEMS

DEFINITIONS

DATUM

Datum is defined in a general sense as the singular of data, or a single piece of information, although it also means the single, fixed data point (or collection of points) that is the beginning or basis of calculation, conclusion, inference, or operation. A datum in a surveying or mapping sense is a horizontal and/or vertical reference system. A major goal in selecting a datum is choosing a reference frame that allows data to be easily projected from prior or nearby projects, or utilized for GIS analysis or mapping.

A horizontal datum can be as localized as a planar basis of bearings, but in a larger sense is the geodetic framework for the project or observation. This applies to the ellipsoid models (and their associated origin, and orientation information) that are used to approximate the shape of the earth or a portion of it. Common models include the GRS80 and WGS84. The North American Datum of 1983 (NAD83) is the official civilian framework for U.S. surveying and mapping activities preformed or financed by the Federal Government (NGS, Federal Register). It incorporates the GRS 80 ellipsoid as well as a large collection of horizontal control monuments and GNSS reference stations (CORS).

A vertical datum, generally, is any level surface to which elevations are referenced. A base elevation for the surface is assigned, somewhat arbitrarily (e.g. generalized "sea level" as elevation zero), and points are measured relative to the surface or to another point in that reference datum. Orthometric datum employ the Earth's gravity field as their datum. Heights referenced to the earth's gravity field can also be called geopotential heights. Three dimensional reference to ellipsoids are another form of vertical datum, allowing for accurate ellipsoid height measurements. Specific relevant examples of a vertical datum include NAVD88, a local municipal set of benchmarks, or the three dimensional reference to an ellipsoid model.

COORDINATE SYSTEMS OR PROJECTIONS

Because of the complexity of performing the calculations for geodetic surveying and the limited extent of most surveying projects, most surveyors generally use plane surveying methods. For local projects, plane surveying yields accurate results, but for large systems (like the department transportation system) local plane surveying systems are not adequate. Not only are local plane coordinate systems inaccurate over large areas, but they cannot be easily related to other local systems.

In response to the needs of local surveyors for an accurate plane surveying datum that is useful over relatively large areas, the U. S. Coast and Geodetic Survey (the predecessor of NGS) developed the State Plane Coordinate Systems. The State Plane Coordinate System was established to provide a means for transferring the geodetic positions of monumented points to plane coordinates that would permit the use of these monuments in plane surveying over relatively large areas without introducing significant error.

A plane-rectangular coordinate system is by definition a flat surface. Geodetic positions on the curved surface of the Earth must be "projected" to their corresponding plane coordinate positions. Projecting the curved surface onto a plane requires some form of deformation. Imagine the stretching and tearing necessary to flatten a piece of orange peel. The orange peel cannot be flattened without deformation of the surface. Similarly, the surface of the earth cannot be represented on a flat plane surface without distortion. A long narrow strip of an orange peel can be flattened with a minimum of distortion. If coordinate systems are limited to long narrow strips a minimum of mapping error results. In Utah the Lambert Conformal map projection is used to transform the geodetic positions of latitude and longitude into the "N" (Northing) and "E" (Easting) coordinates of the Utah Coordinate System of 1983. The Utah Coordinate System of 1983 is defined by law in Utah State Code, Title 57, Chapter 10.

OVERVIEW

Many spatial activities, such as navigation, mapping, and surveying, use geographic coordinates to describe the position of objects. Whenever two activities share a common coordinate system, their data can be more readily compared and exchanged.

For this reason, federal and state mapping products are referenced to two standard coordinate systems: The North American Datum of 1983 (NAD 83) for horizontal positions and ellipsoid heights, and the North American Vertical Datum of 1988 (NAVD 88) for orthometric heights. Surveys are referenced to these datum through measurements to control points of the National Spatial Reference System (NSRS)

NATIONAL SPATIAL REFERENCE SYSTEM (NSRS)

The National Spatial Reference System (NSRS), defined and managed by the National Geodetic Survey (NGS), is a national coordinate system that specifies latitude, longitude, height, scale, gravity, and orientation throughout the Nation, as well as how these values change with time. The NSRS includes a nationwide network of Continuously Operating Reference Stations (National CORS), statewide Federal & Cooperative Base Networks (FBN/CBN), Regional User Densification Networks (UDN), and other historic vertical and horizontal control.

FBN AND CBN

Federal Base Network stations (FBN) or Cooperative Base Networks stations (CBN) are B order accuracy and make up the HARN network. These HARN stations have been observed using GPS and have been either used previously as reference stations in the adjustment of the old conventionally surveyed federal monuments or they are newly placed monuments.

COOPERATIVE CORS STATIONS

Also noteworthy is the systems of Cooperative CORS stations. The main difference between National and Cooperative CORS is that for National CORS site the public obtains the data from NGS, whereas for the Cooperative CORS sites the public obtain the data from site operators. Two examples of Cooperative CORS systems in the State of Utah are the Plate Boundary Observatory CORS stations managed by the UNAVCO consortium, and the VRS or TURNGPS CORS stations managed by the AGRC of the State of Utah. Some of these Cooperative CORS stations are also a part of the NSRS, thus providing a critical link between the two systems.

POLICY

UNITS

Unless otherwise instructed, latitude and longitude will be presented as degrees, minutes and decimal seconds. Direction indicators N or W will prefix the value and seconds will be carried out five places right of the decimal where accuracy is to approximately 0.001 foot.

The coordinate system used by the Department is the Utah Coordinate System of 1983, divided by county into North, Central and South Zones (USC 57-10), however, units of length will be expressed in U.S. Survey Feet, rather than meters. As a minimum, horizontal coordinates should be carried out to 0.001 foot, unless greater accuracies are specified in the projects requirements. Any Department documents identifying or using a coordinate system shall clearly and completely identify the system used, in accordance with USC 57-10 and NGS guidelines: “Utah Coordinate System of 1983 [(2011) epoch 2010.00, *or the current federal coordinate update used as the basis of the system being used*] [North, Central, South] Zone”.

The North American Datum of 1983 (NAD 83) is the horizontal control datum for the United States upon which the coordinate system is founded.

The processing and adjusting of GPS or other similar data may be done in the metric system but all project data must be delivered in U.S. Survey Feet.

The U.S. Survey Foot is defined as one meter being equal to 39.37 inches exact and is represented by the following formula:

$$\text{Meters } (39.37 \div 12) = \text{U.S. Survey Feet}$$

The derived factor is 3.2808333333333. In working with State Plane Coordinates which are presented in the millions, failing to carry the factor out to twelve decimal places will result in error. For this reason use the full and proper formula, rather than a derived scale factor.

COMPUTING PROJECT COORDINATES FROM STATE PLANE

Since surveyors measure on the Earth's surface and not on the mathematical Ellipsoid, a coordinate conversion is necessary to convert from State Plane (Grid) Coordinates to "Project (Ground) Coordinates". Ground distances and angles can be measured and projects can be laid out and constructed working with project coordinates. During location and construction of highway projects, it is much easier to work with project coordinates than with State Plane Coordinates. The procedure is to convert the State Plane Coordinates of the initial control points to Project Coordinates, gather all of the surveying data using Project Coordinates, design the project using Project Coordinates, construct the project using Project Coordinates, then convert the Project Coordinates back to State Plane Coordinates for archiving and future use.

It is very important to understand the difference between project coordinates and Utah State Plane Coordinates. Surveying can be performed in Project Coordinates or Utah State Plane Coordinates. There is however, a difference between the two datum and should never be combined or confused.

The Department policy is to always use Project Coordinates. Experience has shown that far fewer surveying errors occur and the data provided from the Survey crews to the Designers is consistently superior when using project coordinates. Documenting the method used to determine the combined factor and the combined factor itself is critical. The combined factor shall be transferred with all data so future data collection can use the same combined factor.

Any points on the project that vary significantly in elevation as well as projects that run North and South can have an adverse effect on the combination factor. The purpose of using project datum is so that a foot will equal a foot on the ground for location and construction surveying, and to obtain the precision ratio required for the survey work at the Department.

At the beginning of a project, a combination factor needs to be calculated, well documented, and used throughout the project.

The surveyor for the project or region may calculate a combined factor to be used on the project. Additionally, the Region Surveyor also might dictate that a standard county-wide Combined

Factor be used or may ask a consultant to calculate their own. Various methods can be used to arrive at the factor, but it is absolutely necessary that the factor, basis of the factor, and the derivation used are included in the Survey Control Sheet notes (Figure 5-2) and the Record of Survey.

It is mandatory to provide a clear, well-documented explanation of the combination factor and how it was derived to establish the project datum coordinates. The following questions must be answered in documenting the creation of the combined factor:

- What published control points were used for the minimum and maximum latitudes to determine the mean latitude?
- What published control points were used to derive the minimum and maximum orthometric and geoid heights to determine the mean elevation and mean geoid height?
- Were ellipsoid heights used in lieu of orthometric elevations and geoid heights?
- If scale factors were used instead of latitudes, what are the scale factors that were used (scale factors are published on the monument data sheets)?
- Were the numbers and calculations checked independently?

The combined factor shall be carried out to the nine decimal places typically used by NGS, this will produce adjusted coordinates to the ten thousandths of a foot (e.g.1.000359009). Deliberate selection of a scale factor, rather than reliance on a single observation allows a scale factor to be used for multiple projects.

To avoid any confusion with the projects true State Plane Coordinates, care should be taken when developing the projection data that project coordinates are not calculated in the millions by employing false northing and easting offsets and indicating how they are applied in the calculations.

DETERMINING THE COMBINED FACTOR

Determining a Combined Factor is a two-step process, first you determine the project Scale Factor and the project Elevation Factor.

The Scale Factor is determined based on the mean scale factors of the project control that has been established surrounding the project.

The Elevation Factor is determined based on the mean elevation of the project.

Then you calculate a Combined Factor. Multiplying the Scale Factor by the Elevation Factor does this.

SHOWING PROJECT PROJECTION DATA ON SURVEY CONTROL SHEET

Projection data must be shown on the project's Survey Control sheet (Plan Sheet Development Standards).

Survey control notes on the Survey Control Sheet shall include all projection data necessary to recreate the project projection when needed. The notes shall include the following items:

- Project horizontal and vertical datum
- Geoid Model used
- State Plane Coordinate System used
- Units
- False Northing and Easting information and how they were applied in the calculations so that the project coordinate were not in the millions
- Combined Factor
- Convergence Angle
- Coordinate or a description of the point in the project from which the combined factor was applied to scale the data (scaling from the origin of the State Plane Zone applicable to the project is the standard to be used on all Department projects)
- Formula demonstrating how to return to State Plane Coordinates from the project coordinates.

The projection data from the Survey Control Sheet notes shall be added to the project seed files within ProjectWise (See Geo-Referecing MicroStation Seed File).

When the project is completed and ready for archiving, the conversion from project datum coordinates to State Plane Coordinates are calculated in the reverse order. The result is the entire project is then based on the Utah State Plane Coordinates system and ready for archiving, GIS, transfer to others, etc.

CHAPTER 4: CLASSIFICATIONS OF ACCURACY STANDARDS

INTRODUCTION

Survey standards may be defined as the minimum accuracies deemed necessary to meet specific objectives. Specifications are the procedural requirements that will achieve the required accuracy, proving that the survey results weren't a matter of chance, but an indication of the survey's precision. This document provides a common methodology for reporting the accuracy of horizontal and vertical coordinate values for clearly defined features where the location is represented by a point. Examples are active survey monuments, such as Continuously Operating Reference Stations (CORS); passive survey monuments, such as brass disks and rod marks; and temporary points, such as photogrammetric control points or construction stakes. It provides equivalent methods to achieve project requirements, using either positional or proportional methods. It is increasingly important for users to know the coordinate values and the accuracy of those values, so users can decide which coordinate values represent the best estimate of the true value for their application.

The Department standards for survey accuracy are based on the standards set by the Federal Geographic Data Committee's *Geospatial Positioning Accuracy Standards*, specifically FGDC-STD-007.1-1998 (Part 1: Reporting Methodology), FGDC-STD-007.2-1998 (Part 2: Standards for Geodetic Networks), and FGDC-STD-007.4-2002 (*Part 4: Architecture, Engineering, Construction, and Facilities Management*). The federal standards have been modified to create the Department standards, which do not have as many classifications as the federal ones, and are based on the U.S. Survey Foot. However, an understanding of the federal standards will provide a basis for following Department standards.

The *Standards for Geodetic Networks* use metric units as the standards of accuracy, and GNSS surveys can be measured and adjusted in metric units before being converted to U.S. Survey feet. This chapter will use both units, with the required units first, and the equivalent units shown in parenthesis.

POLICIES AND PROCEDURES

All surveys performed on all Department-involved transportation projects will be classified according to the standards shown on the charts in Figures 4-1(A) and 4-1(B). Standards shown are minimum standards for each order of survey. Where practical and allowable, the positional accuracy standards in Figure 4-1(A) will be used instead of the proportional standards described in Figure 4-1(B).

Orders of accuracy classified as “Resource Grade” are shown for the purpose of providing metadata for low order mapping purposes, primarily Geographic Information Systems (GIS) and other database applications. They do not require the use of precision equipment typically used by a survey party. Tolerance requirements for setting construction stakes are provided in Chapter 7, “Construction Surveys.” Tolerance requirements for collecting terrain data are provided in Chapter 6, “Base Mapping Surveys.”

In addition to conforming to the applicable standards, surveys must be performed using field procedures that will meet the required order of accuracy. Specifications for field procedures are provided in Chapter 8, “Global Positioning System (GPS) Survey Specifications,” Chapter 9, “Total Station Survey System (TSSS) Survey Specifications” and Chapter 10, “Differential Leveling Survey Specifications”. Without the use of proper procedures, chance or compensating gross and systematic errors can produce results that indicate a level of accuracy that has not been met.

After standards and specifications, the third requirement that must be met is monument stability. Primary control monuments should have an indefinite life span, while project control monuments need to last at least the life of a project. Supplemental monuments are set as needed for specific purposes, and don't have a specific life span.

FIGURE 4-1A - POSITIONAL ACCURACY

Figure 4-1A - Positional Accuracy

UDOT Order (*See Notes 1 and 2*) (*Note 5*)	STANDARDS			PROCEDURES				TYPICAL APPLICATIONS	
	Relative	Positional Accuracy		Monument Spacing		Survey Methods			
	Standards	Horizontal 95% Confidece Circle	Vertical 95% Confidence Circle	Horizontal (Not to Exceed)	Vertical (Average)	Horizontal	Vertical	Horizontal	Vertical
Sub Centimeter (0.026 sft) Network Accuracy	Supersedes Traditional Order B or Better GNSS Surveys	0.008 m or less (0.026 sft) Network Accuracy	0.008 m or less (0.026 sft) Vertical Network Accuracy Equivalent to First Order Class I Propotional Standards (*See NGS Standards*)	20 Miles	1 Mile	GNSS Static	Use NGS First Order Standards	Regional Control Monuments Basis of Coordinates and Bearings	Used in lieu of FGDC First Order, Class I vertical Control Network Standards (Not Required for UDOT Projects)
One Centimeter (0.03 sft) Network Accuracy	Supersedes First Order GNSS Surveys; Used in lieu of Second Order (Class I) Vertical Surveys	0.010 m or less (0.03 sft) Network Accuracy	Equivalent to Second Order Class I Propotional Standards (*See Figure 4-1B*)	2 Miles	1 Mile	GNSS Static Fast Static (*See Note 3*)	Differential Digital Levels with Invar Bar Code Rod	Primary Project Control Basis of Coordinates/Bearings (*See Note 4*)	Geodetic Control - Used in lieu of FGDC Second Order Class I Proportional Vertical Survey
Two Centimeter (0.07 sft) Network Accuracy	Used in lieu of Traditional Second Order (Class II) GNSS Surveys	0.020 m or less (0.07 sft) Network Accuracy	Equivalent to Second Order Class II Propotional Standards (*See Figure 4-1B*)	2,500 ft	4 Mile	GNSS Static Fast Static Total Station System Traverse	GNSS Static/Fast Static Differential Digital or Optical Levels with Standard Rod	Secondary Project Control Base Stations to be saved for future projects (*See Note 4*)	Used in lieu of FGDC Second Order Class II Proportional Vertical Survey
0.07 sft (Two Centimeter) Local Accuracy	Substitute forTraditional Third Order Horizontal and Vertical Surveys	0.07 sft or less (0.02 m) Local Accuracy	Equivalent to Third Order Propotional Standards (*See Figure 4-1B*)	500 ft or As Required	4,400 ft (10 Turns)	GNSS Static/Fast Static Real Time Kinematic Total Station System Traverse	Differential Digital or Optical Levels with Standard Rod Total Station System Trig Leveling	Cadastral Surveys and Supplemental Control Traverse between Secondary Project Control	Used in lieu of Third Order Proportional Vertical Surveys for GNSS Network Surveys
0.2 sft (Five Centimeter) Local Accuracy	General Order Survey or Mapping Grade	0.2 sft or less (0.05 m) Local Accuracy	N/A	N/A	N/A	GNSS Real Time Kinematic Total Station System Radial within 500 ft	GNSS Real Time Kinematic Total Station System Radial within 500 ft Optical Level or Better	Topographical features (signs, water valves, etc.), High-Risk Utilities, existing culverts	Natural Ground elevations, Utility As-builts
0.3 sft (Ten Centimeter) Local Accuracy	General Order Survey or Mapping Grade	0.3 sft or less (0.1 m) Local Accuracy	N/A	N/A	N/A	As Needed	As Needed	Utility As-builts and 2-D Locations	Utility As-builts
3 sft (One Meter) Resource Accuracy	N/A	3 sft (1 m)	N/A	N/A	N/A	GNSS Receiver with correctional signal	N/A	Locating features for GIS database, such as signs, trees, or drainage pipes	N/A
33 sft (Ten Meter) Resource Accuracy	N/A	33 sft (10 m)	N/A	N/A	N/A	GNSS Receiver without correctional signal	N/A	Locating sites of interest, such as environmentally sensitive areas or accident scenes	N/A

Note 1: Network accuracy is described as the accuracy of a control station that represents the uncertanty of its coordinates with respect to the geodetic datum at the 95-percent confidence level.

Note 2: Local accuracy is the relative accuracy between local control points and represents the uncertainty of its coordinates relative to other directly connected adjacent control points at the 95-percent confidence level.

Note 3: Static GNSS Methods required if baseline lengths are greater than 12 miles - See Chapter 8

Note 4: 1-cm, Network Accuracy is the prefered accuracy for Horizontal Project Control Surveys directly tied to NGS CORS and using the latest NSRS Datum Tag. 2-cm Network Accuracy is the minimum accuracy for Project Control Surveys.

Note 5: The UDOT Positional and Proportional Orders of Accuracy are based on the standards set by the Federal Geographic Data Committee's Geospatial Positioning Accuracy Standards, Specifically FGDC-STD-007.1-1998 (part 1: Reporting Methodology), FGDC-STD-007.2-1998 (Part 2: Standards for Geodetic Networks), and FGDC-STD-007.4-2002 (Part 4: Architecture, Engineering, Construction, and Facilities Management)

Note 6: For the prefered method for obtaining vertical control accuracies see Figure 4-1B -Proportional Accuracy

FIGURE 4-1B - PROPORTIONAL ACCURACY

Figure 4-1B - Proportional Accuracy

<table>
<tr><td rowspan="4">UDOT Proportional Orders (See Note 6)</td><td colspan="3">STANDARDS</td><td colspan="3">MONUMENT SPACING AND SURVEY METHODS (Note 1)</td><td colspan="2" rowspan="2">APPLICATION - TYPICAL SURVEYS</td></tr>
<tr><td colspan="2">CLASSICAL</td><td rowspan="3">POSITIONAL</td><td>MONUMENT SPACING</td><td colspan="2">TYPICAL SURVEY METHOD</td></tr>
<tr><td>Horizontal</td><td>Vertical</td><td>(Typical)</td><td>Horizontal</td><td>Vertical</td><td>Horizontal</td><td>Vertical</td></tr>
<tr><td>Note 1</td><td>Note 1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Second-Order Class I</td><td>1:50,000</td><td>$e=0.025\sqrt{M}$ (Note 2)</td><td>Equivalent to 1 cm Horizontal and Vertical Network Accuracy</td><td>TSS 2300 ft Min Vertical 1 Mile Average</td><td>Total Station Trig-Network</td><td>Digital Bar Code Level with Invar Staff</td><td>Precise Control for structures and tunnels (Not required for typical projects)</td><td>Geodetic Control (Rare)</td></tr>
<tr><td>Second-Order Class II</td><td>1:20,000</td><td>$e=0.035\sqrt{M}$</td><td>Equivalent to 2 cm Horizontal Network Accuracy Only</td><td>TSS 930 ft Min Vertical 1.8 Mile Average</td><td>Total Station Trig-Network</td><td>Digital Bar Code or 3-Wire Optical Leveling</td><td>Project Control - Horizontal Interchange and Major Structure Control</td><td>Preferred Project Control Major Structure Points (Staked)</td></tr>
<tr><td>Third-Order Class I</td><td>1:10,000</td><td rowspan="2">$e=0.050\sqrt{M}$</td><td rowspan="2">Equivalent to 0.07 sft (2 cm) Horizontal and Vertical Local Accuracy</td><td rowspan="2">As Required</td><td rowspan="2">Total Station Network or Traverse</td><td rowspan="2">Digital Bar Code or Optical Leveling Total Station-Trig Leveling</td><td rowspan="2">Supplemental Control
Construction Control
Photo Control - Horizontal
Right-of-Way Surveys (Note 3)
Construction Surveys (Note 4)
Base Mapping Surveys (Note 5)
STLS and MTLS Control Points</td><td rowspan="2">Project Control Vertical
Supplemental Control
Construction Control
Photo Control - Horizontal
Right-of-Way Surveys (Note 3)
Construction Surveys (Note 4)
Base Mapping Surveys (Note 5)
STLS and MTLS Control Points</td></tr>
<tr><td>Third-Order Class II</td><td>1:5,000</td></tr>
<tr><td>General</td><td>1:1,000</td><td>0.1 per 100 feet</td><td>Used in lieu of 0.2 ft Local Accuracy</td><td>N/A</td><td>Total Station Steel or Nylon Tape</td><td>Total Station-Trig Leveling, Single Wire, Direct Elevation Rod, Hand Level</td><td colspan="2">Topographic Surveys (Data Points), Supplemental Design Data Surveys, Construction Surveys (Staked Points), Right of Way Flagging, Asset Inventory Surveys, Archeological Surveys, Environmental Surveys, Historical Preservation Surveys, Monitoring Surveys, Earthwork Surveys such as stockpiles, and borrow pits</td></tr>
</table>

Note 1: Proportional or relative accuracy is described as the ratio between the overall length of a traverse and the misclosure of the final course.

Note 2: M= Distance of level run, in Miles.

Note 3: See Chapter 13 for the accuracy requirements of Right of Way Surveys.

Note 4: See Chapter 7 for the accuracy requirements of Construction stakes.

Note 5: See Chapter 6 for the accuracy requirements of base mapping surveys.

Note 6: The UDOT Positional and Proportional Orders of Accuracy are based on the standards set by the Federal Geographic Data Committee's Geospatial Positioning Accuracy Standards, Specifically FGDC-STD-007.1-1998 (part 1: Reporting Methodology), FGDC-STD-007.2-1998 (Part 2: Standards for Geodetic Networks), and FGDC-STD-007.4-2002 (Part 4: Architecture, Engineering, Construction, and Facilities Management)

ACCURACY AND PRECISION

Several terms are important to understand in determining accuracies required for a project. Several types of accuracy are needed to successfully undertake a surveying project. Also important is the concept of precision.

Accuracy is the degree of conformity with a standard or a measure of closeness to a true value. Accuracy relates to the quality of the result obtained when compared to the standard. The standard used to determine accuracy can be:

- An exact value, such as the sum of the three angles of a plane triangle is 180 degrees.
- A value of a conventional unit as defined by a physical representation thereof, such as the US survey foot.
- A survey or map deemed sufficiently near the ideal or true value to be held constant for the control of dependent operations.

Precision is the degree of refinement in the performance of an operation (instrumentation and procedures) or in the statement of a result. The term precise also is applied, by custom, to methods and equipment used in attaining results of a high order of accuracy, such as using 3-wire leveling methods or a one second theodolite. The more precise the method used in a survey, the higher the probability that the survey results can be repeated. Survey observations can have a high precision, but be inaccurate. For example, observing with a precise theodolite on a day with poor visibility due to heat waves.

Precision is indicated by the number of decimal places to which a computation is carried and a result stated. However, calculations are not necessarily made more precise by the use of tables or factors of more decimal places. The actual precision is governed by the accuracy of the source data and the number of significant figures rather than by the number of decimal places.

Generally, precision is ensured by building redundant measurements into field procedures. Examples include separate GPS observations on the same point under different satellite constellations, three wire leveling, or direct and reverse observations during a traverse. Proper calibration of survey equipment and the balancing of foresights and backsights are other means of maintaining precision.

POSITIONAL AND RELATIVE CLOSURE RATIO ACCURACY

There are two types of survey accuracies that may be specified in Department projects: (1) Positional accuracy or (2) Relative closure ratio (Proportional) accuracy. Positional accuracy standards will be used instead of relative standards when practical and allowable. Surveys conducted by GNSS techniques are always evaluated by positional accuracy. There is no simple correlation between relative closure ratio accuracies and 95% radial positional accuracies; thus, determining a closure order based on a specified feature accuracy requirement is, at best, only an approximation.

POSITIONAL ACCURACY

The standard for reporting positional accuracy is defined in two components: horizontal and vertical. The standard for the horizontal component as published by the NGS is the radius of a circle of uncertainty, such that the true or theoretical location of the point falls within that circle 95% of the time (1.96σ). Department standards are based on Table 2.1 of FGDC-STD-007.2-1998 (*Part 2: Standards for Geodetic Networks*). Most survey adjustments performed for projects will not yield a confidence circle, but an ellipse. The standard for the vertical component is a linear uncertainty value, such that the true or theoretical location of the point falls within +/- of that uncertainty value 95% of the time.

NETWORK AND LOCAL ACCURACY

Monument positions published in NGS datasheets are evaluated using both local and network accuracy values. According to *NOAA Technical Memorandum NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights:*

Network Accuracy - The network accuracy of a control point is a value expressed in cm that represents the uncertainty in the coordinates of the control point with respect to the geodetic datum at the 95 percent confidence level. For National Spatial Reference System (NSRS) network accuracy classification, the datum is considered to be best supported by NGS. By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.

Local Accuracy - The local accuracy of a control point is a value expressed in cm that represents the uncertainty in the coordinates of the control point relative to the coordinates of the other directly connected, adjacent control points at the 95 percent confidence level. The reported local accuracy is an approximate average of the individual local accuracy values between the published control point and the other observed control points used to establish the coordinates of the subject control point. This indicates how accurately a point is positioned with respect to other adjacent points in the local network. Based upon computed relative accuracies, local accuracy provides practical information for users conducting local surveys between control monuments of known position.

When developing local accuracy for datasheets, the NGS uses all measured baselines. In some cases, that can mean baselines over 30 miles long measured many years ago. For this reason, local accuracies in datasheets are often larger than network accuracies at the 95% confidence level.

Department Policy - Regional and project horizontal control monuments must have their locations determined with ties to the National Spatial Reference System NSRS monuments, and the final coordinates are the network accuracy of the monuments.

All surveys that are constrained to regional and project control monuments are considered adjusted to local accuracy. For example, any real time GNSS surveys that use project control for a site calibration, fast static surveys based on project control, or conventional traverses between azimuth pairs, are considered local adjustments.

VERTICAL ACCURACY

The NAVD 88 vertical adjustment has a network accuracy of 5 cm. It was originally based on geodetic quality First Order leveling surveys. In short, the accuracies of the individual surveys that comprise the NAVD 88 realization are more accurate than the final adjustment. Therefore, all vertical surveys performed for project control are considered local accuracy, as they are based on the nearest NAVD 88 monuments, and not part of a national adjustment.

RELATIVE CLOSURE RATIO ACCURACY

The accuracy of surveys may be evaluated, classified, and reported based on closure ratios for the horizontal point or vertical elevation difference, as obtained in the field when points are redundantly occupied". This proportional accuracy standard is applicable to most types of terrestrial survey equipment and practices (e.g., total station traverses and differential leveling). It is the traditional method for evaluating the accuracy of boundary surveys and traverses. All total station and differential leveling surveys will be performed to the specifications for the expected proportional accuracy, even if the intention is to perform a least squares adjustment that will result in a positional accuracy.

The most common way to express proportional accuracy is as the ratio between the overall length of a traverse and the misclosure of the closing course. This can be for a single measurement (i.e. 200 ft, +/- 0.01 ft is a precision ratio of 1:20,000), or for multiple measurements (such as the vertical accuracy expressed as closure times the square root of the traverse distance).

SIGNIFICANT FIGURES

The significant figures of a measurement are those digits which are known plus one estimated digit following the known digits.

Recorded numerical values, both measured and computed, must contain only those digits which are known, plus one estimated digit. When performing calculations, it is common to carry more significant figures than required, and then round off to the proper number of digits for the final answer. If the final digit is "5", the number will be rounded up or down to the nearest even value. A calculated value of 123.415 would be rounded up to a final number of 123.42, while 123.485 would be rounded down to 123.48.

The accuracy of a field survey depends directly upon the precision of the survey. Recorded field measurements should never indicate a precision greater than that used in the actual survey. For example, digital levels measure to the nearest 1 millimeter (0.003 ft.). When converting to the U.S. Survey Foot, the numbers are rounded to nearest whole increment of one hundredth (0.01) of a foot, never converted to the nearest one thousandth (0.001), which would indicate a level of precision the instrument doesn't meet. Similarly, all surveys must be performed with a precision that ensures that the desired accuracy is attained.

ERRORS

Field measurements are never exact. Observations contain various types of errors. Often some of these known errors can be eliminated by applying appropriate corrections. Even after correcting all known errors, all measurements still have error associated to them by some unknown value. It is the responsibility of the Survey Team to perform surveys so that errors fall within certain acceptable standards.

TYPES OF ERRORS

BLUNDERS

Blunders, which are unpredictable human mistakes, are not technically errors. Examples of blunders are: reading and recording mistakes, transposition of numbers, and neglecting to level an instrument. Blunders are generally caused by carelessness, misunderstanding, confusion, or poor judgment. Blunders can usually be detected by computing survey closures, carefully checking recorded and computed values and checking observations. Blunders must be found and eliminated from the work before errors are identified and minimized by adjustment procedure.

SYSTEMATIC ERROR

Systematic errors, given the same conditions, are of the same magnitude and algebraic sign. Because systematic errors have the same sign, they tend to be cumulative. Thermal contraction and expansion of a steel tape and refraction of angular observations are examples of systematic errors. Systematic errors can be eliminated by procedures such as balancing foresights and backsights in a level loop or by applying a correction, such as a temperature correction to a taped measurement. All detected systematic errors must be eliminated before adjusting a survey for random error.

RANDOM ERROR

Random errors do not follow any fixed relationship to conditions or circumstances of the observation. Their occurrence, magnitude, and algebraic sign cannot be predicted. An example of random error is instrument pointing. Because of the equal probability of algebraic sign, random errors tend to be compensating. Procedures and corrections cannot compensate for random error. Random errors must be distributed throughout the survey based on most probable values by adjustment procedures.

Some systematic errors, if undetected, act like random errors. For instance, centering error caused by an optical plummet maladjustment is a systematic error, but the error appears random because the orientation of the tribrach to the line of sight is random. In actuality, even a well-adjusted instrument has some amount of error that is treated as systematic random error.

In statistics, the error is the difference between the measured value and the most likely, or calculated value. If the location of a point is measured more than once, the average of the measurements is considered the most likely value, and the differences between the measured values and the most likely value is the error for each measurement. Generally, the smaller the errors found, the more *precise* the measurement. The more symmetrically the errors are located about the most likely value, the more *accurate* the measurement.

LEAST SQUARES ADJUSTMENT

The least squares method of observation adjustment should be used for the adjustment of most types of Department survey data, whether collected by levels, total stations, or GPS receivers. To be performed correctly, the adjustment is a two-part procedure. First, an unconstrained or free adjustment is done allowing the new observations to be analyzed, their quality determined, and errors detected. Second, a constrained adjustment is performed, which fits the observations to the reference system, thereby determining the coordinate values of the points observed.

CHAPTER 5: SURVEY CONTROL

DESCRIPTION

Control surveys establish a common, consistent network of physical points that are the basis for controlling the horizontal and vertical positions of transportation projects and facilities. Regional control surveys ensure that adjacent projects have compatible control. Project control surveys (Primary/Secondary) provide consistent and accurate horizontal and vertical control for all subsequent project surveys. A control network is the basis of all surveying and mapping activities on a project. Having an accurate network allows for the determination of existing site conditions, preconstruction mapping, design, calculation of quantities, construction surveying including Machine Control Guidance (MCG), and right of way in a precise manner.

The following policies, standards, and procedures are applicable to all control surveys for Department involved transportation projects. This includes surveys performed by Department survey staff, consultants, local agencies, private developers and others.

DEFINITIONS

REGIONAL CONTROL

Regional control surveys are undertaken to establish Geodetic stations spaced along highway corridors approximately 15 miles apart. These control stations, together with the NSRS stations, are used as basic control for all of Department surveying efforts. NSRS and Regional stations, where established, will become the accepted horizontal control network for many surveyors, ensuring consistency between surveys performed by the Department and others.

PRIMARY CONTROL

Primary control points are those used to realize the project datum and coordinate system, they form the basis of all calculation and subsequent survey activities. They must be set or located in an area which will not be disturbed during the duration of the project. The purpose of the primary control is to provide a basis for retracement by using a fixed ground point as a reference for the projects coordinate system.

At a minimum, four controlling points/monuments need to be included in the primary survey control. These points can be monuments of the NSRS, Region stations, PLSS Corners, or other stable monuments. These monuments should be located outside of the planned construction limits.

Points can be primary horizontal control, primary vertical control, or both. The designation of these points whether they are primary points to the horizontal of vertical, and the accuracy level of these points should be shown on the Survey Control Sheet.

SECONDARY CONTROL

Secondary points are control points either established or located based on the primary control. They may be set to aid in surveying or construction activities. Secondary control points are generally horizontal and vertical control points.

Secondary control local accuracy should be set to attain the accuracy requirements for the surveying and staking of the project. Remember, in general, horizontal and vertical control point accuracies should be twice as accurate as positional or elevation tolerances required for features or objects on the site plans or maps (FGDC-STD-007.4.5.1).

When Projects include major structures or machine control guidance (MCG) activities in the construction phase the secondary control should supply a higher density and increased local accuracy than is usually required for conventional methods. See Chapter 7: Construction for more detailed descriptions of the required control for these cases.

SUPPLEMENTAL CONTROL

Supplemental control is used to densify project control surveys. Supplemental control can be used for locating terrain data for engineering surveys, establishing setup points for construction staking, locating cadastral monuments, and setting right of way monuments. Supplemental control points may be used for both horizontal and vertical control.

Supplemental control may include monuments that define or control the horizontal positioning of mapped lines or realize a coordinate system. Mapped lines include: rights of way, boundaries, PLSS lines, municipal limits, and etcetera.

Many monuments may be unsuitable as Primary or Secondary Control points because their stability or permanency of material may be unsuitable in the long term (e.g. fence post, tree, stream centerline), therefore they may be part of the Supplemental Control.

PROJECT BENCHMARKS

Benchmarks are long lasting points for which elevations have been determined, used to control other surveys and to monitor movement of and within the Earth's crust. They constitute the visual evidence of vertical control established by the National Geodetic Survey (NGS).
In Utah the number of federal benchmarks is rapidly being depleted by loss due to improvements of roads and railways. Some of the larger counties and cities have established local benchmark networks, but the majority of the state is only covered by federal benchmarks.

Although construction projects may only require relative heights (an assumed datum), bringing proper vertical control to project areas is advantageous. These bench marks can be used for adjoining projects, saving costs, and detecting errors more easily because checks can be made from more points with common a datum.

A single project benchmark should be selected or established based on the closest Published Benchmark (Primary Control, Regional Control, or NSRS) in relation to the project. All vertical control for the project should be based on this project benchmark using a Vertical Project Control Survey as specified in this chapter. Care should be taken to reference this project benchmark beyond the limits of the project to minimize the loss of said benchmark throughout the duration of the project.

POLICY

Horizontal Regional control surveys shall be performed along transportation corridors where multiple improvement projects are planned. Regional Control shall be based on the NSRS.

Horizontal project control surveys (Primary/Secondary) shall be performed for all Department involved transportation projects using NSRS and Regional coordinates to define the geographic positions of project facilities.

Vertical project control surveys shall be performed for each Department involved transportation project that requires elevations to define the positions of fixed works.

Horizontal project control surveys (Primary/Secondary) should be based on (tied and adjusted to) three or more NSRS or Regional stations. If a Horizontal Project Control Survey network “tie” to the nearest NSRS or Regional station exceeds 20 kilometers, establishment of additional Regional station(s) shall be considered.

When feasible, horizontal project control shall be established using GPS surveys complying with Department 1-cm network accuracy standard. When GPS survey methods cannot be used for all or part of a Horizontal Project Control Survey, a Total Station Survey traverse network meeting the Department second-order accuracy standard is acceptable. See Chapter 4, “Classifications and Accuracy Standards.”

Vertical project control surveys shall be based on a single, common vertical datum to ensure that various phases of a project and contiguous projects are consistent. The preferred vertical datum for Department involved improvement projects is the North American Vertical Datum of 1988 (NAVD88).

PLANNING AND RESEARCH

RESPONSIBILITY

The planning and design phases of the project development process require appropriate mapping and field surveys. Project control surveys provide the basis and framework for base maps and digital terrain models used in the development of contract plans and acquisition of right of way. As soon as a project requiring Surveys involvement is known, e.g., initial survey request is received, a Project Surveyor/Consultant should be chosen by the Project Manager in conjunction with the Region Surveyor (PLS). The Project Surveyor should be an active participant on the Project Development Team to provide advice and input on survey related matters and issues, be responsible for initiating control surveys, and respond to project survey needs.

PLANNING

The Project Surveyor/Consultant is responsible for planning and establishing the project control network. Project control (Primary/Secondary) surveys should be planned to provide convenient horizontal and vertical survey control for right of way design, base mapping, engineering, construction, and monumentation surveys for the duration of the project. A work plan for establishing the project control should be developed after consulting the following individuals:

- Project Manager
- Project Engineer
- Region Surveyor (PLS)
- Region Right of Way Manager

Planning the control network so that it will meet the needs of all subsequent project surveys is critical. Key steps in the control planning process are to:

- Ascertain the need for additional Regional control
- Develop a survey work schedule that meets the needs of the Project Development schedule.
- Research the existing horizontal and vertical control networks.
- Recover and evaluate existing control.
- Decide on the vertical datum for the project (NAVD88 preferred).
- Plan the project control network and select the methods for establishing control.
- Plan supplemental control.

If possible, project control should be planned so that project control monuments serve for both horizontal and vertical control. It is important that project control plans consider the need for supplemental control.

RESEARCH

The Project Surveyor/Consultant will conduct a thorough search of Department records to determine the availability of existing control in the project area. New coordinate values, based on the NSRS, should be determined for existing control using field observations and network adjustments. All horizontal control, including conversions of existing control, should be based on the NSRS. Another source of control information is the NGS.

For vertical control, research may be expanded beyond Department surveys files and NGS to include other State, Federal, County and local agencies.

SUGGESTED OFFICE PREPARATIONS

The Project Surveyor/Consultant, in consultation with the field supervisor and party chief, is responsible for the development of the necessary instructions and information (field package) for performing required control surveys. Surveys office staff, under the direction of the Project Surveyor/Consultant, generally prepare a field package using information obtained from research, together with other compiled and computed data. Field packages should contain all the necessary information and data to efficiently complete the field work required for establishment of control networks. Typical information to include in the field package is:

- Expenditure authorization and time recording sheet information.
- Copy of the original survey request.
- Right of entry information, conditions, and permits.
- Criteria for selection of survey method.
- Predetermined positions of control monuments and anticipated project alignments.
- Copies of pertinent research materials (record of survey maps, parcel maps, tract maps, and subdivision maps.
- Department right of way and monumentation maps.

Existing aerial photographs.

- Station “to reach” information.
- Reference ties and related data for existing horizontal control monuments.
- Vertical control monument locations, descriptions, and elevations.

FIELD WORK

RECONNAISSANCE

Prior to initiating a Control Survey a thorough search and recovery of existing horizontal and vertical control monuments in the immediate area of the project is required. Also, a field reconnaissance will be required before final control net planning is accomplished and field work is begun. Recovered control monuments must be evaluated before being used as a basis for new control surveys. All recovered points should be fully described in the survey notes.

Controlling monuments or points that will be disturbed by construction activities need to be perpetuated after construction. Noting on the design sheets (roadway and right of way) that a monument is to be protected in place or will be removed is required by plan sheet development standards. Controlling monuments such as PLSS corners will require coordination with the County Surveyor or designated county officer. Removal of monuments of other varieties may require additional coordination.

HORIZONTAL REGIONAL CONTROL SURVEYS

Each Region Surveyor should develop a systematic plan for completing Regional control surveys. Region-wide or area-wide High Precision Geodetic Networks (HPGN) surveys are the preferred method for establishing Regional control. When large area densification surveys are planned, cooperative agreements for performing the work should be established with local agencies and private sector surveyors. This will ensure that the Regional stations are accepted as the "best" control for the local surveying community.

When ties to NSRS or Region stations, for purposes of establishing project control are longer than 30 miles, additional Region stations should be established in conjunction with project control. Exceptions to this policy shall be determined by the Region Surveyor based on current and future project development needs and available resources.

METHOD

Region control surveys must be performed using GPS surveys. See Chapter 8, "Global Positioning System (GPS) Survey Specifications."

Note: Survey procedures and documentation must conform to NGS specifications if survey results will be submitted to NGS for inclusion in the National Spatial Reference System (NSRS).

ACCURACY

Surveys must be referenced and adjusted to NSRS stations and meet Department Sub Centimeter (0.026 sft) Network Accuracy, per FIGURE 4-1A – POSITIONAL ACCURACY.

MONUMENTATION

Monuments shall be located along transportation corridors in secure locations. The station site shall be selected with safety considerations for the surveyor and others given highest priority. Sites within or adjacent to the traveled way of limited access highways should be avoided. Monuments shall be accessible to the public, preferably in a public right of way or easement. Typical locations are:

- Along freeway ramps near the junction of the right of way for the ramp and the local street.
- Within county or city street right of way.
- Bridge abutments (if on piles).
- On public property or at public facilities (canals, parks, etc.).

Whenever possible select station locations that can be easily described. When several locations are equally satisfactory choose the one that is near features that will aid in future monument recovery.

Monuments shall be constructed to ensure permanency. Monument type shall be chosen to suit the local conditions and be tailored to meet the minimum accuracy requirements for the individual project. See U.S. Army Corps of Engineers Manual EM 1110-1-102, Survey Markers and Monumentation, Fig 3-1 and 3-2 for guidelines comparing the types of monuments with the positional accuracy of the survey. Based on the positional accuracy required and the site conditions prevailing in the State of Utah, typically the chosen monument for Regional Control should be as follows:

- Types A, B, C, or G from the above referenced U.S. Army Corps of Engineers Manual
- Any of the four types of monuments shown in “Attachment B - New or Replacement Survey Monuments”, from the NGS Guidelines, entitled “Bench Mark Reset Procedures”, 2010.
- Existing NGS monuments in good condition and equal to or exceeding the permanency provided by above standards.
- Other existing or new monuments, if they meet or exceed the permanency of the above standards and are approved by the Region Surveyor (PLS).

If the survey results will be included in the NSRS, use monument disks specifically designed and manufactured for NSRS surveys stamped with the calendar year of the survey and the station identification. If another agency is the primary sponsor of the densification survey be sure that the disks used are stamped with an appropriate notation.

HORIZONTAL PROJECT CONTROL SURVEYS

Horizontal project control surveys establish control for transportation projects. All subsequent horizontal surveys for a project are based on the horizontal project control. Horizontal Project control may consist of Primary Control points and Secondary Control Points. Horizontal Control must be established with the end use of the project taken into consideration. The density of the control must be sufficient to meet the tolerances and accuracy needed. In the case of a project with Machine Control Guidance, additional horizontal control may be needed.

METHOD

Whenever feasible, horizontal project control shall be established using GPS survey methods. See Section 6, “Global Positioning System (GPS) Survey Specifications.” When GPS survey methods cannot be used for all or part of a horizontal project control survey, the TSS system can be used. See Chapter 9, “Total Station System (TSS) Survey Specifications.”

Some horizontal project control surveys are hybrid projects with TSS networks bracketed by GPS azimuth pairs at the beginning, end, and at intervals throughout the project.

ACCURACY

Horizontal project control surveys must be referenced and adjusted to NSRS and/or Region stations. Preferred order of accuracy is Department One Centimeter (0.03 sft) for Primary Control Points and Two Centimeter (0.07 sft) for Secondary Control Points, per FIGURE 4-1A – POSITIONAL ACCURACY.

MONUMENTATION

Monuments shall be located along transportation corridors in secure locations. The station site shall be selected with safety considerations for the surveyor and others given highest priority. Sites within or adjacent to the traveled way of limited access highways should be avoided. Monuments shall be accessible to the public, preferably in a public right of way or easement. Typical locations are:

- Along freeway ramps near the junction of the right of way for the ramp and the local street.
- Within county or city street right of way.
- Bridge abutments (if on piles).
- On public property or at public facilities (canals, parks, etc.).

Whenever possible select station locations that can be easily described. When several locations are equally satisfactory choose the one that is near features that will aid in future monument recovery.

Monuments shall be constructed to ensure permanency. Monument type shall be chosen to suit the local conditions and be tailored to meet the minimum accuracy requirements for the individual project. See U.S. Army Corps of Engineers Manual EM 1110-1-102, Survey Markers and Monumentation, Fig 3-1 and 3-2 for guidelines comparing the types of monuments with the positional accuracy of the survey. Based on the positional accuracy required and the site conditions prevailing in the State of Utah, typically the chosen monument for Primary/Secondary Project Control should be as follows:

- Types A, B, C, or G from the above referenced U.S. Army Corps of Engineers Manual
- Any of the four types of monuments shown in “Attachment B - New or Replacement Survey Monuments”, from the NGS Guidelines, entitled “Bench Mark Reset Procedures”, 2010.
- Existing NGS monuments in good condition and equal to or exceeding the permanency provided by above standards.
- Other existing or new monuments, if they meet or exceed the permanency of the above standards and are approved by the Region Surveyor (PLS).
- The preferred monuments for Secondary Control are specified above, however due to the number and less permanent nature of secondary control points, less permanent monuments such as spikes, iron pipes, rebar, etc. may be used.

If the survey results will be included in the NSRS, use monument disks specifically designed and manufactured for NSRS surveys stamped with the calendar year of the survey and the station identification. If another agency is the primary sponsor of the densification survey be sure that the disks used are stamped with an appropriate notation.

VERTICAL PROJECT CONTROL SURVEYS

A vertical project control survey shall be performed for each specific Department involved transportation project that requires elevations to define topographic data points or positions of fixed works. The establishment of vertical project control monuments is important because all subsequent project surveys requiring elevations are to be based on the vertical project control. Vertical Project control may consist of Primary Control points and Secondary Control Points.

When feasible, vertical control for projects should be established at all horizontal control stations. Additional benchmarks should be set to densify vertical control to provide convenient control for photogrammetry, topographic, and construction purposes. Although construction may only require relative heights (an assumed datum), bringing proper vertical control to project areas is advantageous in that bench marks can be used for adjoining projects, saving costs, errors and can more easily be detected by having more points in common to check against.

Elevations of benchmarks, which are part of the National Spatial Reference System, can be obtained online from the National Geodetic Survey at http://www.ngs.noaa.gov. The data sheets for vertical control give the (1) approximate geodetic coordinates for the station, (2) adjusted North American Vertical Datum of 1988 (NAVD88) elevation, (3) observed or modeled gravity reading at the station, and (4) a description of the station and its location among other things. The NGS benchmark should be verified for reliability, check to determine that it has not been disturbed and seems suitable before being relied upon.

The surveyor should clearly understand the contract requirements and scope of work before selecting a methodology to establish project elevations.

METHOD

Vertical Project Control can be established using the following methods:

- Differential leveling, see Chapter 10, “Differential Leveling Survey Specifications.”
- Trigonometric leveling, see Chapter 9 “Total Station System (TSS) Survey Specifications.”
- GPS can be used to bring NAVD88 to a project. See Chapter 8 “GPS Surveys."

ACCURACY

Preferred accuracy standard is Department Second-Order Class II survey accuracy, although Department Third-Order Class I accuracy is acceptable. See Chapter 4, FIGURE 4-1B – PROPORTIONAL ACCURACY.

MONUMENTATION

Monuments shall be located along transportation corridors in secure locations. The station site shall be selected with safety considerations for the surveyor and others given highest priority. Sites within or adjacent to the traveled way of limited access highways should be avoided. Monuments shall be accessible to the public, preferably in a public right of way or easement. Typical locations are:

- Along freeway ramps near the junction of the right of way for the ramp and the local street.
- Within county or city street right of way.
- Bridge abutments (if on piles).
- On public property or at public facilities (canals, parks, etc.).

Whenever possible select station locations that can be easily described. When several locations are equally satisfactory choose the one that is near features that will aid in future monument recovery.

Monuments shall be constructed to ensure permanency. Monument type shall be chosen to suit the local conditions and be tailored to meet the minimum accuracy requirements for the individual project. See U.S. Army Corps of Engineers Manual EM 1110-1-102, Survey Markers and Monumentation, Fig 3-1 and 3-2 for guidelines comparing the types of monuments with the positional accuracy of the survey. Based on the positional accuracy required and the site conditions prevailing in the State of Utah, typically the chosen monument for Primary/Secondary Project Control should be as follows:

- Types A, B, C, or G from the above referenced U.S. Army Corps of Engineers Manual
- Any of the four types of monuments shown in "Attachment B - New or Replacement Survey Monuments", from the NGS Guidelines, entitled "Bench Mark Reset Procedures", 2010.
- Existing NGS monuments in good condition and equal to or exceeding the permanency provided by above standards.
- Other existing or new monuments, if they meet or exceed the permanency of the above standards and are approved by the Region Surveyor (PLS).
- The preferred monuments for Secondary Control are specified above, however due to the number and less permanent nature of secondary control points, less permanent monuments such as spikes, iron pipes, rebar, etc. may be used.

If the survey results will be included in the NSRS, use monument disks specifically designed and manufactured for NSRS surveys stamped with the calendar year of the survey and the station identification. If another agency is the primary sponsor of the densification survey be sure that the disks used are stamped with an appropriate notation.

SUPPLEMENTAL CONTROL

METHOD

- Differential leveling, see Chapter 10, "Differential Leveling Survey Specifications."
- TSS surveys, see Chapter 9 "Total Station System (TSS) Survey Specifications."
- Global Positioning System, see Chapter 8 "Global Positioning System (GPS) Survey Specifications."

ACCURACY

Supplemental control surveys shall meet Department 0.07 sft (Two Centimeter) Local Accuracy, or third-order survey accuracy for both horizontal and vertical control. See Chapter 4, FIGURE 4-1A – POSITIONAL ACCURACY and FIGURE 4-1B – PROPORTIONAL ACCURACY.

MONUMENTATION

Generally monumentation for supplemental control is temporary. Monuments should be set where needed, but out of the way of construction and in stable ground. Examples of temporary monuments are: spikes, concrete nails, iron pipes, rebar, etc.

CONTROL NETWORK DESIGN SPECIFICATIONS

To meet a network or local accuracy level, a control survey must be connected to sufficiently accurate and well-distributed existing control.

All of the control stations to which the network will be constrained must have positions known on the NSRS or Region Control system. Certain special projects may have a legitimate need for another geodetic reference. Use the appropriate datum adjustment as recommended by the Department's Region Surveyor.

The minimum number of horizontal and vertical constraints is stated in Figure 5-1 of the "Minimum UDOT Network Design Specifications" with their location being distributed in different quadrants relative to the center of the project. Where existing NSRS or Region control (horizontal and/or vertical) on a common datum and epoch is available, all such stations lying within a few miles of the survey's boundaries should, if possible, be included in the survey if they meet the horizontal accuracy requirements. NSRS Second order or better is generally required for vertical.

FIGURE 5-1 - MINIMUM UDOT NETWORK DESIGN SPECIFICATION

FIGURE 5-1 Minimum UDOT Network Design Specifications

Level of Accuracy	**Sub cm (0.026 sft)**	**cm (0.033 sft)**	**2 cm (0.066 sft)**
Minimum Number of Closest Direct CORS Ties	2	1	0
Minimum Number of Total FBN/CBN /CORS Station Ties	4	3	2 *(See Note 1)*
Minimum Number of Horizontal Station Ties	4	3	2
Minimum Number of Vertical Ties (2nd order or better)	5	4	2
Minimum Number of Occupations Per Station	2	2	2
Minimum Number of Repeat BL's (% of all BL's)	40%	30%	20%
Time Offset Between Observations *(Occupations See Note 2)*	± 3 hrs	± 2 hrs	± 1 hrs
Minimum Satellite Elevation Mask	15 Degrees	13 Degrees	13 Degrees
Minimum Number of Quadrants for Horizontal Station Ties	4	3	2
Minimum Number of Quadrants for Vertical Station Ties	4	4	2
Type of Ephemerix Required	Precise	Rapid or precise	Broadcast or better

Notes:

1. These ties should be at least indirect ties to NSRS stations. They may be surveyed from Regional control stations, which have been tied to NSRS stations.

2. To qualify for a new occupation, the observer must remove the GPS receiver at the station and a completely new setup over the station must take place.

S

DELIVERABLES

SURVEY CONTROL SHEET

The Project Surveyor/Consultant shall prepare a project Survey Control Sheet for each project control survey. The diagram shall be a schematic drawing of the horizontal network, including the r/w north arrow cell (narro2) with the proper township and range, title block, survey date, date of preparation, legend and vicinity map, if applicable. Display and label control points, township and range, section, and quarter section lines, and additional monuments; where necessary, use additional sheets as needed. Section Corners are to be located adjacent to the project for the length of the project, see Right of Way Design Manual, and are to be included as part of the survey control sheet and labeled as either found and not found. Label the type of monument for found monuments. Use correct cells to display control points and monuments. Provide a description of monument or a sketch of the monument found. (Description would include all data available on monument.) If bar scale is not shown, a note stating "Not to Scale" shall be provided. Display and gray-scale the existing topography but turn off levels, as needed, to avoid clutter. A Utah licensed surveyor must digitally sign and stamp this sheet. The diagram shall show the horizontal control monuments established, and the NSRS and Region control stations that were used as the basis for the survey with appropriate symbols, monument names, and coordinate table reference numbers, if applicable. Vertical control monuments shall be shown in their location on the diagram.

The project Survey Control Sheet shall include a note that bearings, distances, and coordinates are based on the NSRS Coordinate System and another note naming the datum used for vertical control. The Utah Coordinate System note shall state the current datum federal coordinate update, including the epoch, the zone of the system, project mapping angle(s), and project combination factor(s).

The Survey Control Sheet shall be created in accordance with the UDOT Plan Sheet Development Standards

The project Survey Control Sheet should contain a coordinate table which includes the following:

- Monument names/Point Number.
- Horizontal coordinates of each monument (N,E).
- Latitude and Longitude shown in DD°MM'SS.SSSSS"
- Project Elevation carried out to 2 decimal places.
- State Plane Coordinate.
- Least squares adjustment residuals for new control points.
- Coordinate dates (epochs).
- Descriptions of each monument.
- Identify the points in table as either Primary Control or Secondary Control.
    - Separate tables can be used for Primary Control and Secondary Control.

    - Primary controls are the points used for horizontal and vertical positional accuracy.
    - Secondary control is located after primary control is established for ease of resurvey.
- Survey Control Notes
    - Project Datum (e.g. NAD 83)
    - Vertical Datum (e.g. NAVD 88)
    - Geoid Model (e.g. Geoid12A (conus))
    - Coordinate System (e.g. Utah Coordinate System of 1983 (2011) epoch 2010.00, Central Zone)
    - Units (U.S. feet)
    - False Northing and False Easting information and how applicable to calculations.
    - Project Coordinates are not to be in the millions
    - Scale Factor or Combined Adjustment Factor (CAF)
    - Coordinate or description of the point project was scaled from.
    - Scaling from the origin of the Utah Zone (North, Central, South) applicable to
        - the project is the standard to be used on all projects. (Point being 0, 0 state
        - plane coordinate for applicable zone.)
    - Formula of how to return to State Plane Coordinates
    - Describe Regional Control and NSRS used as a basis for survey.
    - Date of survey

The project Survey Control Sheet shall be retained (archived) as part of the project control report.

The Survey Control Sheet shall be complete and delivered at the scoping phase of the project, including certification by a Utah Professional Land Surveyor. The sheet will be delivered to the Region Surveyor for a quality assurance check. See Figure 5-2

All files must be named and placed in accordance with the UDOT CADD Standards Manual and submitted into UDOT ProjectWise System and attributed properly.

The Survey Control Sheet shall show the accuracy of the survey in accordance with Figures 4-1A/4-1B, and shall be signed and sealed by the Professional Land Surveyor in responsible charge of the work.

The Survey Control sheet shall be accompanied by all field notes used in the survey (printouts or electronically recorded field notes). The following files shall be included with the Project Control Report:

- **Original Field Data**
    - File describing the Basis of Survey Elements and Datum in accordance with Department Standards
    - File containing original field survey notes or raw field data when obtained with Data Collectors. The raw data in Level, DC, RINEX, or DAT file, or

other data controller formats and log sheets must also be preserved for future retrieval.

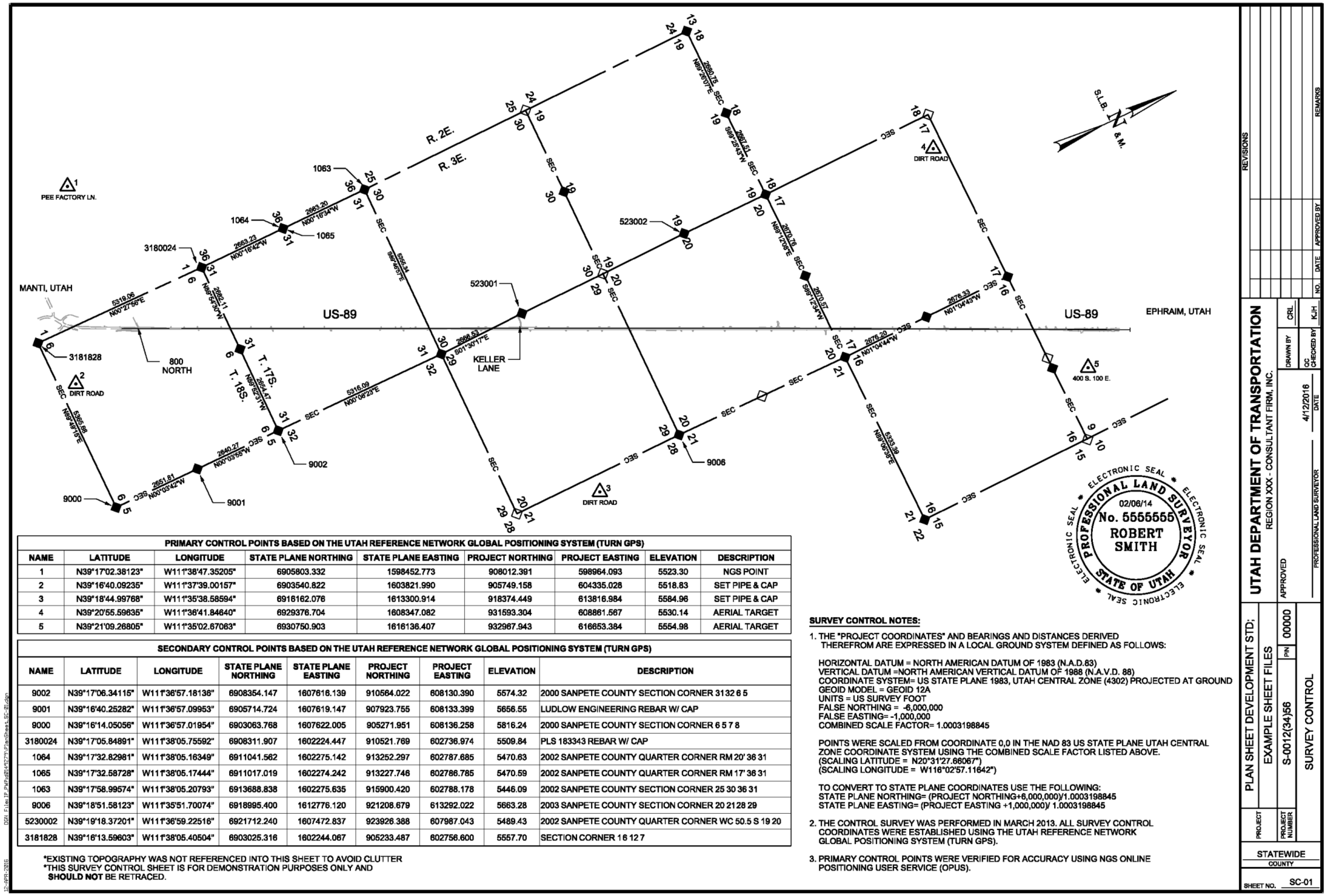
- **Descriptions for all Monuments and control points included in the control Survey**
    - File containing Control Data Sheets used for Primary Control Points
    - File containing the description and photographs of each control point
    - File containing Corner Records in accordance with 17-23-17.5 and the Utah Council of Land Surveyors (UCLS) Guide for Preparing Corner Records in Utah
    - Note: Items b and c may be combined into one
- **Survey Reduction Computations**
    - File containing all data reduction computations including leveling data, horizontal control with adjustments for closure, and LiDAR registration reports if applicable.
    - The final list of coordinates from the survey should include all metadata necessary to make the coordinates usable. This would include datum used (and adjustment such as HARN), units, state plane or surface adjusted, and if surface adjusted, the adjustment factor used. Coordinates shall include standard Department feature codes. Most often the format desired is: point name, northing, easting, elevation, feature code, notes, and level of accuracy met.
    - As an indicator of the survey quality, a project summary should be printed as supplied by the software. It will indicate the above information about the baseline processing and the adjustment routine. Such items as histograms and bell curves, ratios of precision for each point, etc. are generally available for review.
    - All data shall be georeferenced in accordance with requirements under the General Specifications Section.
        - Final survey control file containing calibration, parameters, etc. that is ready for delivery for use by the contractor for verification and other purposes.
- **Survey Control Sheet QC/QA Package**
    - File containing QC/QA activities including Survey/Mapping QC Checklist and the Checklist from the Guide for the Development of Plan Sheets for the Survey Control Sheet.

SPECIAL CONSIDERATION FOR REGION CONTROL SURVEYS

Regional control surveys should be coordinated with the Region Surveyor. Each regional control survey shall be either submitted to NGS for inclusion in the National Spatial Reference System (NSRS) or be filed with the County Surveyor as a Record of Survey. The preferred method is to submit the survey for inclusion in the NSRS, so that all Region stations will be included in the NSRS and any future NGS adjustments. For requirements for submittal to NGS, see *Input Formats and Specifications of the National Geodetic Survey Data Base, I. Horizontal Control Data*, National Geodetic Survey.

FIGURE 5-2: SURVEY CONTROL SHEET EXAMPLE

The figure below is for information only, See [UDOT Plan Sheet Development Standards]() for detailed instructions on requirements.



PRIMARY CONTROL POINTS BASED ON THE UTAH REFERENCE NETWORK GLOBAL POSITIONING SYSTEM (TURN GPS)

NAME	LATITUDE	LONGITUDE	STATE PLANE NORTHING	STATE PLANE EASTING	PROJECT NORTHING	PROJECT EASTING	ELEVATION	DESCRIPTION
1	N39°17'02.38123"	W111°38'47.35205"	6905803.332	1598452.773	908012.391	598964.093	5523.30	NGS POINT
2	N39°16'40.09235"	W111°37'39.00157"	6903540.822	1603821.990	905749.158	604335.028	5518.83	SET PIPE & CAP
3	N39°18'44.99768"	W111°35'38.58594"	6916162.076	1613300.914	918374.449	613816.984	5584.96	SET PIPE & CAP
4	N39°20'55.59635"	W111°36'41.84640"	6929376.704	1608347.082	931593.304	608861.567	5530.14	AERIAL TARGET
5	N39°21'09.26805"	W111°35'02.67063"	6930750.903	1616136.407	932967.943	616653.384	5554.98	AERIAL TARGET

SECONDARY CONTROL POINTS BASED ON THE UTAH REFERENCE NETWORK GLOBAL POSITIONING SYSTEM (TURN GPS)

NAME	LATITUDE	LONGITUDE	STATE PLANE NORTHING	STATE PLANE EASTING	PROJECT NORTHING	PROJECT EASTING	ELEVATION	DESCRIPTION
9002	N39°17'06.34115"	W111°36'57.18136"	6908354.147	1607616.139	910564.022	608130.390	5574.32	2000 SANPETE COUNTY SECTION CORNER 31 32 6 5
9001	N39°16'40.25282"	W111°36'57.09953"	6905714.724	1607619.147	907923.755	608133.399	5656.55	LUDLOW ENGINEERING REBAR W/ CAP
9000	N39°16'14.05056"	W111°36'57.01954"	6903063.768	1607622.005	905271.951	608136.258	5816.24	2000 SANPETE COUNTY SECTION CORNER 6 5 7 8
3180024	N39°17'05.84891"	W111°38'05.75592"	6908311.907	1602224.447	910521.769	602736.974	5509.84	PLS 183343 REBAR W/ CAP
1064	N39°17'32.82981"	W111°38'05.16349"	6911041.562	1602275.142	913252.297	602787.685	5470.63	2002 SANPETE COUNTY QUARTER CORNER RM 20' 36 31
1065	N39°17'32.58728"	W111°38'05.17444"	6911017.019	1602274.242	913227.746	602786.785	5470.59	2002 SANPETE COUNTY QUARTER CORNER RM 17' 36 31
1063	N39°17'58.99574"	W111°38'05.20793"	6913688.838	1602275.635	915900.420	602788.178	5446.09	2002 SANPETE COUNTY SECTION CORNER 25 30 36 31
9006	N39°18'51.58123"	W111°35'51.70074"	6918995.400	1612776.120	921208.679	613292.022	5663.28	2003 SANPETE COUNTY SECTION CORNER 20 21 28 29
5230002	N39°19'18.37201"	W111°36'59.22516"	6921712.240	1607472.837	923926.388	607987.043	5489.43	2002 SANPETE COUNTY QUARTER CORNER WC 50.5 S 19 20
3181828	N39°16'13.59603"	W111°38'05.40504"	6903025.316	1602244.067	905233.487	602756.600	5557.70	SECTION CORNER 1 6 12 7

*EXISTING TOPOGRAPHY WAS NOT REFERENCED INTO THIS SHEET TO AVOID CLUTTER
*THIS SURVEY CONTROL SHEET IS FOR DEMONSTRATION PURPOSES ONLY AND **SHOULD NOT** BE RETRACED.

SURVEY CONTROL NOTES:

1. THE "PROJECT COORDINATES" AND BEARINGS AND DISTANCES DERIVED THEREFROM ARE EXPRESSED IN A LOCAL GROUND SYSTEM DEFINED AS FOLLOWS:

   HORIZONTAL DATUM = NORTH AMERICAN DATUM OF 1983 (N.A.D.83)
   VERTICAL DATUM =NORTH AMERICAN VERTICAL DATUM OF 1988 (N.A.V.D. 88)
   COORDINATE SYSTEM= US STATE PLANE 1983, UTAH CENTRAL ZONE (4302) PROJECTED AT GROUND
   GEOID MODEL = GEOID 12A
   UNITS = US SURVEY FOOT
   FALSE NORTHING = -6,000,000
   FALSE EASTING= -1,000,000
   COMBINED SCALE FACTOR= 1.0003198845

   POINTS WERE SCALED FROM COORDINATE 0,0 IN THE NAD 83 US STATE PLANE UTAH CENTRAL ZONE COORDINATE SYSTEM USING THE COMBINED SCALE FACTOR LISTED ABOVE.
   (SCALING LATITUDE = N20°31'27.66067")
   (SCALING LONGITUDE = W116°02'57.11642")

   TO CONVERT TO STATE PLANE COORDINATES USE THE FOLLOWING:
   STATE PLANE NORTHING= (PROJECT NORTHING+6,000,000)/1.0003198845
   STATE PLANE EASTING= (PROJECT EASTING +1,000,000)/ 1.0003198845

2. THE CONTROL SURVEY WAS PERFORMED IN MARCH 2013. ALL SURVEY CONTROL COORDINATES WERE ESTABLISHED USING THE UTAH REFERENCE NETWORK GLOBAL POSITIONING SYSTEM (TURN GPS).

3. PRIMARY CONTROL POINTS WERE VERIFIED FOR ACCURACY USING NGS ONLINE POSITIONING USER SERVICE (OPUS).

CHAPTER 6: BASE MAPPING SURVEY

Prior to the base mapping survey being performed, a meeting between the surveyor, the project manager, and design lead will be held in order to anticipate the needs for the project.

Some topics for the meeting could include but is not limited to:

- Schedule
- Survey needs
- Recommended type of survey method
- Accuracy requirements based on project type. (E.g. Automated Machine Guidance, 3D Engineered Models, etc.)
- Extents of project survey
- Features needed for survey
- Other needs determined by the project manager, designer, or surveyor.
- Past projects with developed control systems

TOPOGRAPHIC SURVEY

The topographic survey is performed to determine the shape, configuration, relief, and three-dimensional characteristics of the earth's surface.

Use standard Department Survey codes on all projects. If a code is needed that is not included in the standard codes it may used, but must be noted and included in the project's Civil .XIN file with included feature definition and assigned symbology.

A topographic survey should be of sufficient quality and accuracy in order to create a Digital Terrain Model (DTM) that is sufficient for the needs of the project as determined during the Project Setup meeting. The topographic survey must meet the minimum tolerances shown in Figure 6-1.

FIGURE 6-1 - LOCATION SURVEY ACCURACY STANDARDS

Figure 6-1 Location Survey Accuracy Standards

LOCATION SURVEY TYPE	ACCURACY STANDARDS	
	Horizontal	Vertical
Topographic/As-Built Surveys - (Paved Surfaces or Engineering Works) (Natural Ground Points)	± 0.06 ft ± 0.15 ft	± 0.05 ft ± 0.15 ft
Pavement Elevation Surveys - Rehabilitation and other improvements of existing facilities which require accurate elevations of existing pavements *(See Note 1)*	± 0.05 ft	± 0.03 ft
Utility As-Built Surveys - (Above Ground Features or Engineering Works) (See Note 2)	± 0.2 ft	± 0.2 ft
Subsurface Utility Surveys - (Designating Services, per ASCE Guideline 38-02) (Locate Services/Test Hole, per ASCE Guideline 38-02)	± 1 ft ± 0.1 ft	N/A ± 0.1 ft
Archaeological Site/Environmentally Sensitive Area Surveys *(See Note 3)*	± 0.5 ft	± 0.5 ft
Spot Location or Monitoring Surveys - (Paved Surfaces or Engineering Works) (Natural Ground Points) (See Note 4)	± 0.08 ft ± 0.15 ft	± 0.05 ft ± 0.15 ft
Vertical Clearance Surveys - (Paved Surfaces or Engineering Works) (Natural Ground Points)	± 0.1 ft ± 0.1 ft	± 0.1 ft ± 0.1 ft

Notes:

1. Pavement Elevation Surveys are one of the most hazardous surveys performed on Department projects. It is imperative that safe surveying practices be employed for such surveys.

2. Some utility locations may require more stringent accuracies than shown herein due to possible conflicts with other utilities, topographic features or design limitations. Adjust the method and accuracies expected to the purpose of the survey.

3. Review field survey package for possible higher required accuracy.

4. Some spot checking and monitoring may require more stringent accuracies than shown herein. Adjust the method and accuracies expected to the purpose of the survey.

Validate the 3D Model in the Base Mapping

In order to validate the 3D model in the base mapping for a given project the mapping professional shall:

- Provide an independent validation survey consisting of a minimum of 20 horizontal check points and 20 vertical check points.
- Use the validation survey to statistically evaluate the base mapping 3D model against the desired accuracy level for areas of interest in the project.
- Deliver a report of this survey and analysis to the Project Manager and the Region Surveyor before the base mapping product is approved for use in the project.

UDOT HORIZONTAL ACCURACY STANDARDS FOR 3D MODELS

Horizontal Accuracy Class (1)	RMSEx and RMSEy (sft)	RMSEr (sft)	Absolute Accuracy Horizontal Accuracy at 95% Confidence Level (sft)	Description
X-sft	≤ X	≤ 1.414*X	≤ 2.448*X	Formula
0.08 sft (2.5 cm)	≤ 0.08 sft	≤ 0.11 sft	≤ 0.20 sft	Typically preferred for hardscapes
0.16 sft (5 cm)	≤ 0.16 sft	≤ 0.23 sft	≤ 0.39 sft	Typically preferred for softscapes

1. These Horizontal Accuracy Classes are taken from ASPRS Table B.6 which presents 24 common horizontal accuracy classes for digital planimetric data.
2. The Table above specifies the primary horizontal accuracy standard for digital mapping data. This standard defines horizontal accuracy classes in terms of their RMSEx and RMSEy values.

UDOT VERTICAL ACCURACY STANDARDS FOR 3D MODELS

Vertical Accuracy Class (1)	Absolute Accuracy		Description
	RMSEz (sft)	95% Confidence Level (sft)	
X-sft	≤ X	≤ 1.96*X	Formula
0.08 sft	≤ 0.08	≤ 0.16 sft	Typically preferred for

(2.5 cm)	sft		hardscapes
0.16 sft (5 cm)	≤ 0.16 sft	≤ 0.31 sft	Typically preferred for softscapes

1. Vertical Accuracy Classes are taken from ASPRS Table B.7 which provides vertical accuracy examples and other quality criteria for ten common vertical accuracy classes.

Testing 3D Models

Horizontal accuracy shall be tested by comparing the planimetric coordinates of well-defined points in the 3D Model with coordinates of the same points from an independent set of observations. Vertical accuracy shall be tested by comparing the elevations in the 3D Model with elevations of the same points as determined from an independent set of observations.

The independent set of observations shall be acquired separately from data used in the 3D model solution. The independent set of observations shall be of the highest accuracy feasible and practicable to evaluate the accuracy of the 3D Model. Independent quality control may be conducted by a different survey firm or region. Independent checks may also be done by the same firm or region by methods approved by the Region Surveyor, by making observations independently of the topographic survey by separate setup.

Ideally, a validation dataset should be an order of magnitude more accurate than the network or local accuracy specification requested for the 3D Model, however, this is a challenge given that there are limited technologies that would meet this criterion. For example, control for a project will normally be set using GNSS – long duration static occupations for highest accuracy (sub-cm), RTK for faster evaluation (a few cm), terrestrial scanning (cm), or total station/digital leveling (sub-cm) depending upon the required accuracy of the resultant product. Further, while instruments such as a total station provide very high local accuracy, coordinates still must be tied to control for network accuracy evaluations. Leveling can provide high vertical accuracy (sub-mm), but does not provide the ability to assess horizontal accuracy.

There should always be more than 20 points used for the quality control (QC) evaluation to compute 95% confidence (FGDC1998). The validation points must differ from the control points used for the 3D Model. Additionally, these points should be widely distributed throughout the project in order to reflect variance across the project extents. If the primary data of interest is not in the road, it is recommended that validation points be acquired on the features of interest.

Reporting 3D Model Accuracies

Horizontal and vertical accuracies shall be reported in terms of compliance with the RMSE thresholds and estimated accuracy at a 95% confidence level in accordance with the FGDC NSSDA standards.

- Accuracy statements shall specify that the data are “tested to meet” the standard of accuracy.
- For select projects, where the Region Surveyor does not require testing, accuracy statements should specify that the data are “produced to meet” the stated accuracy.
- The horizontal accuracy of digital mapping data sets shall be documented in the metadata in the following manner:
  - “This data set was tested to meet UDOT Positional Accuracy Standards for 3D Models, at a ____(sft) RMSEx/RMSEy Horizontal Accuracy Class, Actual positional accuracy was found to be RMSEx = ____ (sft) and RMSEy = ___ (sft) which equates to Positional Horizontal Accuracy = ± ____ sft at a 95% confidence level.” The mean of the vertical variation of check shots used to determine measured accuracy was 0.071 sft.
- The vertical accuracy of elevation data sets shall be documented in the metadata in the following manner:
  - “This data set was tested to meet UDOT Positional Accuracy Standards for 3D Models, at a ____(sft) RMSEz Vertical Accuracy Class, Actual NVA accuracy was found to be RMSEz = ____ sft, equating to ± ___ sft at 95% confidence level.” The mean of the vertical variation of check shots used to determine measured accuracy was 0.071 sft.

Survey Narrative Report

The surveyor in charge should prepare a survey narrative report containing, at a minimum, the following information for the subject project:

- Project name and location;
- Survey date, time, weather conditions, limits and purpose;
- Project datum, epoch and units;
- Horizontal time-dependent positioning (HTDP) parameters, if used;
- System calibration report;
- Survey control points found, held and set (see Control survey report);
- Personnel, equipment, and surveying methodology employed;
- Problems encountered, if any;
- Other supporting survey information, such as GNSS observation logs; and
- Dated signature and seal of the surveyor in charge.

Control Survey Report

For those applications that require the use of higher-order survey control networks, 3D Model data must be traceable back to the published primary control. This data lineage must be clearly defined and documented in the control survey report such that an independent third party could duplicate the results. At a minimum the report should contain information on:

- Primary control held or established;
- Project control held or established;
- Local transformation points;
- Validation points;
- Adjustment report for control and validation points;
- Base station observation logs (occupation data, obstruction diagram, atmospheric conditions, etc.);
- GNSS accuracy report with details on time, duration and location of any loss of signal lock;
- GNSS satellite visibility and PDOP reports;
- IMU accuracy report;
- Trajectory reports including locations of loss of signal lock exceeding a specified threshold (typically 60 seconds) and operating speeds during acquisition;
- Results of comparisons between validation points and the 3D Model to assure that contracted project specifications have been met (Table D.1 shows an example of a spreadsheet for testing the 3D Model data set);
- A continuous, color-coded point density map with summary statistics for objects of interest and for the entire project area.

FIGURE 6-2 - (Table D.1) NSSDA Accuracy Statistics for Example Data with 3D Coordinates

Table D.1 NSSDA Accuracy Statistics for Example Data set with 3D Coordinates

Point ID	Map-derived values			Survey Check Point Values			Residuals (Errors)		
	Easting (E)	Northing (N)	Elevation (H)	Easting (E)	Northing (N)	Elevation (H)	Δx Easting (E)	Δy Northing (N)	Δz Elevation (H)
	Meters	Meters	Meters	Meters	Meters	Meters	Meters	Meters	Meters
GCP1	359584.394	5142449.934	477.127	359584.534	5142450.004	477.198	-0.140	-0.070	-0.071
GCP2	359872.190	5147939.180	412.406	359872.290	5147939.280	412.396	-0.100	-0.100	0.010
GCP3	395893.089	5136979.824	487.292	359893.072	5136979.894	487.190	0.017	-0.070	0.102
GCP4	359927.194	5151084.129	393.591	359927.264	5151083.979	393.691	-0.070	0.150	-0.100
GCP5	382737.074	5151675.999	451.305	372736.944	5151675.879	451.218	0.130	0.120	0.087
Number of check points							5	5	5
Mean Error (m)							-0.033	0.006	0.006
Standard Deviation (m)							0.108	0.119	0.006
RMSE (m)							0.102	0.107	0.081
RMSEr (m)							0.147	=SQRT(RMSEx^2+RMSEy^2)	
NSSDA Horizontal Accuracy, (ACCr) at 95% Confidence Level							0.255	=RMSEr x 1.7308	
NSSDA Vertical Accuracy, (ACCz) at 95% Confidence Level							0.160	=RMSEz x 1.9600	

1. Table D.1 shows the method of computation at the 95% Confidence Level for NVA conditions.
2. Sample computations follow for the Mean Error, Standard Deviation, RMSE, and Positional accuracy at the 95% confidence level.

Computation of Mean Errors in x/y/z:

$$\bar{x} = \frac{1}{(n)}\sum_{i=1}^{n} x_i$$

where:

x_i is the i^{th} error in the specified direction

n is the number of checkpoints tested.

i is an integer ranging from 1 to n.

Mean error in Easting:

$$\bar{x} = \frac{-0.140 - 0.100 + 0.017 - 0.070 + 0.130}{5} = -0.033\text{m}$$

Mean error in Northing:

$$\bar{y} = \frac{-0.070 - 0.100 - 0.070 + 0.150 + 0.120}{5} = 0.006\text{m}$$

Mean error in Elevation:

$$\bar{z} = \frac{-0.070 + 0.010 + 0.102 - 0.100 + 0.087}{5} = 0.006\text{m}$$

Computation of Sample Standard Deviation:

$$s_x = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}$$

where:

x_i is the i^{th} error in the specified direction,

$\bar{x}$ is the mean error in the specified direction,

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

Sample Standard Deviation in Easting:

$$s_x = \sqrt{\frac{\left(-0.140-(-0.033)\right)^2 + \left(-0.100-(-0.033)\right)^2 + \left(0.017-(-0.033)\right)^2 + \left(-0.070-(-0.033)\right)^2 + \left(0.130-(-0.033)\right)^2}{(5-1)}}$$
$$= 0.108\text{m}$$

Sample Standard Deviation in Northing:

$$s_y = \sqrt{\frac{\left(-0.070-0.006\right)^2 + \left(-0.100-0.006\right)^2 + \left(-0.070-0.006\right)^2 + \left(0.150-0.006\right)^2 + \left(0.120-0.006\right)^2}{(5-1)}}$$
$$= 0.119\text{m}$$

Sample Standard Deviation in Elevation:

$$s_z = \sqrt{\frac{\left(-0.071-0.006\right)^2 + \left(0.010-0.006\right)^2 + \left(0.102-0.006\right)^2 + \left(-0.100-0.006\right)^2 + \left(0.087-0.006\right)^2}{(5-1)}}$$
$$= 0.091\text{m}$$

Computation of Root Mean Squares Error:

$$RMSE_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_{i(map)} - x_{i(surveyed)}\right)^2}$$

where:

$x_{i(map)}$ is the coordinate in the specified direction of the i^{th} checkpoint in the data set,

$x_{i(surveyed)}$ is the coordinate in the specified direction of the i^{th} check-point in the independent source of higher accuracy,

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

$$RMSE_x = \sqrt{\frac{(-0.140)^2 + (-0.100)^2 + (0.017)^2 + (-0.070)^2 + (0.130)^2}{5}} = 0.102\text{m}$$

$$RMSE_y = \sqrt{\frac{(-0.070)^2 + (-0.100)^2 + (-0.070)^2 + (0.150)^2 + (0.120)^2}{5}} = 0.107\text{m}$$

$$RMSE_z = \sqrt{\frac{(-0.071)^2 + (0.010)^2 + (0.102)^2 + (-0.100)^2 + (0.087)^2}{5}} = 0.081\text{m}$$

$$RMSE_r = \sqrt{RMSE_x^{\,2} + RMSE_y^{\,2}}$$

Positional Horizontal Accuracy at 95% Confidence Level =

$$2.4477\left(\frac{\text{RMSE}_r}{1.4142}\right) = 1.7308(\text{RMSE}_r) = 1.7308(0.148) = \mathbf{0.255m}$$

Vertical Accuracy at 95% Confidence Level =

$$1.9600(\text{RMSE}_z) = 1.9600(0.081) = \mathbf{0.160\ m =}$$

$$\sqrt{\left(\left(0.102^2\right) + \left(0.107^2\right)\right)} = 0.148\text{m}$$

DELIVERABLES

The topographic Survey shall be supplied to the Department, and shall be complete and acceptable to the Region Surveyor.

All files must be named and placed in accordance to the UDOT CADD Standards Manual, Plan Sheet Development Standards, and submitted into UDOT ProjectWise System.

- Survey Report
    - Document shall include a description of control used, the Basis of Survey Elements, datum, measurements completed, computations made, and accuracies attained. The document shall be signed and sealed by the Professional Land Surveyor who supervised the work.
    - Confidence report outlining validation procedure and derived accuracy factor of topographic surface. Define percentile of confidence for hard and soft surfaces as part of this report.
    - The survey report shall be accompanied by all field notes used in the survey or printouts or electronically recorded field notes.
- Original Field Data
    - File containing original field survey notes or raw field data when obtained with electronic data collectors. The raw data in DC, RINEX or DAT file format and log sheets must also be preserved for future retrieval.
- Cleaned up topographic survey in MicroStation OpenRoads Format.
    - The topographic survey should be free of any code errors and all breaklines and features connected and not overlapping.
    - All features, linework, cells, and text need to be scaled based on UDOT CADD Standards.
    - Any additional created cells need to be included with the deliverable in a MicroStation Cell Library.
    - The files must be named according to the UDOT CADD Standards.
- A digital terrain model (DTM) created from the topographic survey in MicroStation Open Roads format. Open Roads format requires the files to be integrated into the CADD file and not a standalone DTM file.
- Report with an explanation of the accuracy and density of the DTM model for hard and soft surfaces.

CHAPTER 7: CONSTRUCTION SURVEYS

GENERAL

This chapter is to be used for all transportation improvement projects, including special funded projects. It shall be used by all Department employees or consultants performing construction surveys. It is their responsibility to adhere to all relevant processes, workflow, and provisions stated in this chapter. The Contractor will schedule a coordination meeting with the surveyor who completed the survey control and topography to discuss and clarify any questions or concerns regarding the survey work performed within 7 days of Notice to Proceed and before beginning work.

TOLERANCES

Tolerances stated for each type of construction stake in this chapter indicates the acceptable deviation of the position of each reference point from its computed position relative to the given alignment and grade. When the stake is positioned within its tolerances, it is deemed "good." Staked positions are generally checked using electronic stakeout reports and, if within tolerances, the stated position is accepted. For precise measurements such as structures, reference points may also have an accuracy relative to each other.

Tolerances should not be confused with accuracy standards. Accuracy is a function of the random errors associated with the survey methods and procedures that are used for the whole survey project, including project control, construction control, and construction survey set-up points. For construction surveys, survey accuracy standards indicate the expected variation in positions based on random errors for the set-up points, not variations in the construction stakes themselves. (See Figure 7-1)

FIGURE 7-1 - CONSTRUCTION STAKING TOLERANCES

CONSTRUCTION STAKING TOLERANCES		
Description	**Horizontal**	**Vertical**
	Decimals of a foot	
Box Culverts, Headwalls	± 0.02	± 0.02
Bridge Superstructures	± 0.02	± 0.02
Bridge Substructures	± 0.02	± 0.02
Clearing and Grubbing Stakes	± 1.00	-----
Construction Centerline Control Points	± 0.05	-----
Construction Centerline Station Points	± 0.10	-----
Curbs, Walks, and Bike Paths	± 0.03	± 0.02
Grade Stakes – Roadway Subgrade	± 0.20	± 0.05
Grade Stakes – Top of Rock	± 0.20	± 0.03
Grade Stakes – Roadway Finish	± 0.10	± 0.02
Luminaire and Signal Poles (incl.	± 0.20	± 0.20
Manholes, Inlets, and Culverts	± 0.10	± 0.03
PCC Pavement	± 0.10	± 0.02
Slope Stakes and References	± 0.30	± 0.10
Traffic Markings	± 0.20	-----
Walls – Retaining, MSE, Sound, etc.	± 0.10	± 0.05
Wetland Mitigation Control Stakes	± 0.20	± 0.20

Stakes for miscellaneous items not listed above will have a horizontal and vertical tolerance of 0.20 foot, unless otherwise directed. Features that are to constructed flush to another surface should take on the same tolerance as that surface.

Staking tolerances for special circumstances will be discussed at the pre-survey meeting.
In constructing the work, the contractor shall meet the appropriate construction tolerances for the material as specified in the special provisions or standard specifications, regardless of the construction staking tolerances, specific to the work item.

STRUCTURE CONTROL NETWORK

STRUCTURE SURVEY CONTROL STATIONS

Structure Survey Control Stations – Use a minimum of 4 control points for establishing the structure control network. Additional points may be set as needed, however, use the smallest number of original project control stations as is practical for establishing positions and reference points for the construction on the structure. Use control stations that are as closely related mathematically as practical. The Contractor may establish additional control stations as necessary to complete the survey work. Additional control stations shall be established in such a manner as to provide the accuracy needed to meet the tolerances in Figure 7-1 Construction Staking Tolerances. Use structure control once established, independent of other project controls for the duration of the structure construction.

Original Project Control stations shall be used only after the following evaluation is completed for each structure:

- Supply a list of the original project horizontal and vertical control stations intended to be used by the contractor in establishing positions of a given structure.
- Measure relative positions of the original horizontal and vertical control stations intended to be used.
- Supply horizontal and vertical measurement data to the Resident Engineer upon request.
- Compare measured values with those computed from the original horizontal and vertical networks.
- Any discrepancy of concern to either the Contractor or the Resident Engineer will be resolved before that combination of control stations is used.

MAJOR STRUCTURES AND BRIDGES

Set stakes, nails, or other devices to control the location and elevation of the various parts of the structures and progressive phases of construction. Provide horizontal and vertical control for all elements of the structure construction. Stake drainage facilities, electrical conduits, water and sewer pipes, pedestrian and bicycle facilities, traffic signal and sign supports, illumination devices, and other items shown or identified that are to be integrated into the construction of the structure.

Identify marks or provide field notes or reports to the Resident Engineer (RE). Such provision of information shall be adequate for the RE to review the location and elevation of the mark for the intended purpose prior to incorporating material that is based on the mark.

SUBSTRUCTURE

Stake, reference, or otherwise identify locations, orientations, and elevations necessary for the placement of substructure components, including but not limited to cofferdams, pilings, drilled shafts, footings, columns, abutments, caps, cross beams, bearing devices, temporary supports or false-work, and excavations and embankments associated with any of the above.
Verify and document the locations, elevations and spatial relationships with adjacent substructure components. On bridges where prefabricated beams will be used, measure and document span lengths between devices at each beam location as soon as practical. Supply a copy of such documentation to the Resident Engineer for review before the next stage of construction.

SUPERSTRUCTURE

Stake, reference, or otherwise identify locations, orientations, and elevations necessary for the placement of substructure components, including but not limited to beams, girders, diaphragms, earthquake restraints, deck, rails, structure mounted traffic control and illumination devices, and concrete forms, temporary supports and false-work associated with any of the above.
Stake alignment of structure as needed at each stage of construction. Stake alignment of poured-in-place items at 10 foot stations or as established by the Resident Engineer.

BRIDGE DECK GRADES

Set stakes or other devices to control the deck grade elevations. The exact process will depend upon the type of deck and the equipment being used.

Control of a Portland Cement Concrete (PCC) deck may involve significant work with the deck placement crew to establish control for a deck finishing machine. Rails for supporting the deck finishing machine are generally set up on either side of the deck. Each rail is held up by adjustable supports every 5 feet. Adjust the rail at each support to the desired grade while the rail is supporting the weight of the finishing machine.

Control of an Asphalt Concrete (AC) deck will not generally involve as many variables as PCC. An AC deck serves as a wearing surface, but not a structural component. Asphaltic concrete will frequently be used as filler to create the desired super elevations when flat beams form the superstructure. Stake control of the finished grade like any asphalt finish grade. Under some circumstances, design camber and structural deflection may need to be considered.

CHECKING

Sufficient independent field checks must be made at the discretion of the Resident Engineer to assure the integrity of the construction stakes. The integrity of radial stakeout set-up points should be verified before use by making check measurements from other control points and measuring the distances between set points. All positions staked in the field should be checked against the computed positions and the results recorded in electronic stakeout reports and/or on stakeout listings.

FIELD NOTES

Construction survey field notes in the form of electronic stakeout reports, stakeout listings with actual staked positions noted, or suitable forms, will be filed with the Resident Engineer upon completion of the survey. The Resident Engineer will provide copies to the Contractor upon request.

MACHINE CONTROL GUIDANCE (MCG)

Machine Control Guidance (MCG) technology uses positioning devices, alone or in combination to determine real time X, Y, and Z positions of construction equipment and compare that position against a 3D digital terrain model (DTM). A computer display shows the operator or grade checker several perspectives and delta values of their position compared to the design surface. This technology has the potential to increase the Contractor’s efficiency, productivity, and reduce the number of survey stakes required, thus reducing the number of construction working days. The construction industry is currently implementing MCG and the Department has developed interim guidelines to foster its use.

SUPPLEMENTAL MCG PROJECT CONTROL

MCG may require a higher density of control monuments than needed for conventional methods. Setting additional monuments for machine guidance is part of construction staking. The Contractor must utilize and constrain to the provided project survey control points for the Digital Terrain Model (DTM), DDM, and construction equipment locations to match.
GNSS satellite signals can be subject to interference from canyons, buildings, trees or even fencing and power lines. Additional monuments will be set when needed for adequate site coverage. Not all locations are suitable for MCG techniques, and it is the Contractor’s responsibility to determine if the site conditions are practical for MCG.

Robotic total station guided equipment, such as paving machines, require a more dense survey control network of a higher order of vertical accuracy than GNSS controlled systems.
Control should be staggered on either side of the highway to provide a good strength of figure. Typically the distance between control points set for MCG should be no farther than 650 ft, the actual distance may vary by the type of equipment used by the contractor. The instrument setup must obtain vertical accuracies within ± 0.02 ft of the existing control.

AS-BUILT SURVEY

In order to keep the Departments assets database current; a complete as-built must be submitted at the end of the project. The as-built will be collected during the entire construction phase in order to capture all features on the project both above and below grade. The as-built shall be collected to accuracies shows on Figure 6-1.

Standard UDOT Survey codes will be used on all department projects for as-built collection. If a code is needed that is not included in the standard survey codes it may used, but must be noted, included in the UDOT Civil .XIN file with included feature definition and assigned symbology.

Items that will be required in the as-built will include but not limited to: All assets that are exposed below grade. (e.g. exposed utilities, drainage, and other pertinent features as determined by the Resident Engineer.) Above grade assets (e.g. curb and gutter, roadway slope, pavement section, roadway crown, sidewalk, driveway locations, barrier, guardrail, and other pertinent features as determined by the Resident Engineer.) Everything that is included in the design files and any additional supplemental items added or anything that was discovered during construction.

All files must be named and placed in accordance to the UDOT Cadd Standards Manual, Plan Sheet Development Standards, and submitted into UDOT Projectwise System.

AS-BUILT DELIVERABLES

The as-built survey shall include a discussion of control used, measurements completed, computations made, and accuracies attained. The survey report shall be accompanied by all field notes used in the survey or printouts or electronically recorded field notes. The as-built survey must be of sufficient accuracy for the intended purpose of the project as discussed during the preliminary meeting. The as-built survey shall be collected to survey grade accuracies, and shall be signed and sealed by the Professional Land Surveyor who supervised the work. The following files shall be included:

- Original Field Data
  - File describing the Basis of Survey Elements and Datum in accordance with Department Standards
  - File containing original field survey notes or raw field data when obtained with Data Collectors. The raw data in the native data collector format. (e.g. DC, RINEX, RW5, ASCII, or DAT) file format and log sheets must also be preserved for future retrieval.
- Cleaned up topographic as built survey in DGN Format or other compatible format as approved by the Technology Advancement Engineer.

    - The topographic survey should be free of any code errors and all breaklines and features connected and not overlapping.
    - All features, linework, cells, and text need to be scaled based on UDOT Cadd Standards.
        - Any additional created cells need to be included with the deliverable in a MicroStation Cell Library.
        - The files must be named according to the UDOT Cadd Standards.
- Provide all survey data needed to ensure the as-built 3D Model can be generated including all assets as directed by the Technology Advancement Engineer.

CHAPTER 8: GPS SURVEY

GPS STATIC SURVEYING

Static GPS surveying typically uses a network or multiple baseline approach for positioning. It may consist of multiple receivers, multiple baselines, multiple observational redundancies and multiple sessions. A least squares adjustment of the observations is required. This method provides the highest accuracy achievable and requires the longest observation times; from less than an hour to five hours or longer.

Static positioning is primarily used for ties to the National Spatial Reference System (NSRS) when observing for Department Sub cm Level and cm Level surveys. Project control points are nearly always set using this type of survey.

A variation of the static survey is the fast-static method (also called rapid-static by some manufacturers of GPS equipment). This will allow shorter occupation times (i.e., 8 to 20+ minutes) than static positioning and may use a radial baseline technique, network technique, or a combination of the two. Baseline lengths may not exceed 6 miles for L1 only receivers and 12 miles for L1/L2 receivers.

Typically, the occupation time is a minimum of 8 minutes for baseline up to 12 miles and a minimum of 12 minutes for baselines up to 19 miles. Please refer to manufacturers' specifications for minimum occupation times, number of satellites observed, and minimum amount of cycle slip free data collected for this type of data collection method. Fast-Static requires a least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations. More than one base station will be used to provide redundancy for each vector. Fast-Static techniques may be used for observing 2 cm and 3-5 cm Levels.

PLANNING

Planning is one of the most important parts of the performance of a control survey utilizing GPS survey measurement techniques. Care should be taken to understand the specifications included in Figure 4-1 Accuracy Classification, Figure 5-1 Network Design, and Figure 8-1 GPS Positional Specifications while planning a control survey. The following steps will help to ensure the creation of a baseline network, which will produce accurate coordinates on newly placed project points:

- Roughly locate both new points and existing control on a map showing roads to use in moving the observers around the project.
- During field reconnaissance flag and mark points for easy identification by all personnel.
- For each session draw independent baselines intended for observation on a map. Move through the project until all points have been included.

- From an almanac of satellite orbits choose appropriate times for observations to avoid. Consider space weather – unusually poor conditions caused by solar storms and magnetic disturbances can cause many hours of unusable data. One measure of this activity is the Kp index. An explanation of this scale and daily predictions can be found at http://www.sec.noaa.gov/index.html.
- When possible, separate redundant observations by 24 hours to consider different atmospheric conditions and then a several hour shift to take advantage of a slightly different satellite constellation.
- Observing the above suggestions, plan your repeated occupations and observations. Make a schedule understandable to all personnel doing the fieldwork.

When designing the network, it is good practice to use a minimum of three (3) horizontal control points and four (4) vertical control points because two (2) horizontal and three (3) vertical control points are required to define transformation parameters. The additional horizontal and vertical control points can be used to check the consistency of the adjustment and defined transformation parameters. Adding additional control points builds more confidence in the calculated parameters. Sub cm and 1 cm Levels do require these three - four (3 - 4) horizontal coordinates and four - five (4 -5) elevations at a minimum, See FIGURE 8-1.
The field reconnaissance survey of the site mentioned above should accomplish the following:

- Determine the location and sky visibility of existing and new control stations
- Pick the locations for new stations making sure satellites can be recorded in a minimum of three quadrants
- Look at logistics of project and determine transportation required
- Gain permission to access station(s) on private land
- If applicable, notify law enforcement of your activities
- Record sky visibility chart data and access requirements for all stations
- Look for any objects that could be sources for radio interference
- Look for any multi-path conditions that may affect data collection

FIGURE 8-1 - GPS POSITIONING SPECIFICATIONS

Figure 8-1

GPS Positioning Specifications				
Level	Sub cm (0.026 sft)	cm (0.033 sft)	2 cm (0.066 sft)	3-5 cm (0.098 - 0.164 sft)
Typical job type	Major control densification	Primary Project control	Property corners, secondary project control, flight panels	Topo surveys, and non-critical layout
Type of GPS	static	static	fast static or RTK	RTK
GPS Positioning Relative to Other Points (Local Accuracy)				
Instrument setup error	2 mm (0.006 sft) for B order monuments	2 mm (0.006 sft)	3 mm (0.019 sft)	5 mm (0.033 sft)
Total baseline length error at 2 sigma	8 mm +1 ppm (0.026 sft + 1 ppm)	8 mm +1 ppm (0.026 sft + 1 ppm)	12 mm +1 ppm (0.039 sft + 1 ppm) (see Note 1)	20 mm +1 ppm (0.066 sft + 1 ppm) (see Note 1)
Maximum baseline length for referencing from CORS station	200 km (124 miles)	200 km (124 miles)	N/A	N/A
Maximum baseline length between points on a project	100 km (62 miles)	25 km (15 miles)	5 km (3 miles) (no limits within a VRS cell)	5 km (3 miles) (no limits within a VRS cell)
Minimum time per occupation	2 hrs + 1 min per km baseline	1 hr + 1 min per km baseline	180 epochs with rod rotated 180 degrees between observations	3 epochs (see Note 2)
Minimum number of occupations for static network (see Note 3)	2 for B order	2	2	N/A
Minimum time between occupations	3 hrs	2 hrs	1 hr	N/A

FIGURE 8-1 (Continued) - GPS POSITIONING SPECIFICATIONS

GPS Positioning on the State Plane Grid (Network Accuracy)				
Level	Sub cm (0.026 sft)	cm (0.033 sft)	2 cm (0.066 sft)	3-5 cm (0.098 - 0.164 sft)
Horizontal accuracy at 2 sigma	12 mm (0.039 sft)	20 mm (0.066 sft)	25 mm (0.082 sft)	45 mm (0.148 sft) (see Note 4)
Elevation				
Accuracy at 2 sigma (assuming 100% perfect geoid model)	22 mm (0.073 sft)	25 mm (0.082 sft)	30 mm (0.099 sft)	40 mm (0.132 sft) (see Note 5)

Note 1 - RTK baselines are measured from base station to rover point.

Note 2 - This should not be confused with 3 seconds - depending on conditions, it usually takes approx 5 to 10 seconds for 3 useable epochs.

Note 3 - A complete new setup is required for each occupation.

Note 4 - This should not be confused with project (local) accuracy wich is 20 mm + 1 ppm in relation to radius points, traverse points and other secondeary control as shown in above "Local Accuracy Specifications.

Note 5 - The vertical component is not acceptable for most stakeout operations.

FIELDWORK

The normal collection rate (epoch) is 5 seconds for static observations but for long observation times of more than 3 hours, a collection rate 30 seconds is acceptable.

Longer baselines will require longer total observation times on end points. Please refer to Figure 8-1, and manufacturers' specifications for minimum occupation times. Allowances should be made for difficult situations where there may be less satellite visibility, high PDOP, chance of reflected signal or even solar flares and sunspots.

The H.I., antenna type, and serial number must be recorded in a field book or on log sheets for every occupation. The log sheets may contain other information but their main purpose is to pass on to the processor the H.I. of the setup and match the location to the particular data file. See recommended data sheet format at the following link:
http://www.ngs.noaa.gov/PROJECTS/NGSforms/obslog-OPUS.pdf

There should be one log sheet per observation. At the end of the day or the end of the project, the party chief, knowing the number of observations, must collect all of the completed data sheets. One missing data sheet may require the repeat of an entire session because it is not possible to redo a single missing point since simultaneous occupations must be made.
The elevation mask should not be set at less than 13 degrees – 15 degrees is normally used, see Figure 8-1. Data from satellites lower than that is just about useless for surveying; it is too noisy going through the atmosphere. Anything over 15 degrees may be denying the processor access to useful data that he or she may need in some situations. Usually the processing is done at a cut-off elevation of 15 or 17 degrees.

All observers should be well aware of the scheduled start and stop times for each session and should allow plenty of time to find the monument (which should be well marked and flagged before the day of the observation) and allow enough time to set up the antenna accurately.

FAST-STATIC (RAPID STATIC) POSITIONING

The method of Fast-Static/rapid static positioning requires shorter occupation times than static positioning (i.e. 8 to 20 + minutes) and may use a radial baseline technique, network technique, or a combination of the two. Baseline lengths may not exceed six (6) miles for L1 only receivers and twelve (12) miles for L1/L2 receivers.

Accuracy degrades at a predictable rate with this type of survey; therefore, longer baselines may be used when design survey quality is not needed. Please refer to the manufacturer's specifications for minimum occupation times, number of satellites observed, and minimum amount of cycle slip free data collected for this type of data collection method.

Fast-Static requires a least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations. More than one base station will be used to provide redundancy for each vector.

Fast-Static or rapid static techniques could be used for observing 2 cm & 3-5 cm Levels listed in Figure 8-1. It provides baselines that do not exceed the maximum distances stated above in the first paragraph of this subsection.

BASE LINE PROCESSING

When loading the observations into the base line processor software, care should be taken that each file includes the correct antenna type, antenna height, and type of measurement. Remember that on CORS and Cooperative CORS stations, the measurement is from the antenna reference point (ARP) – this is also the point of reference for all RINEX files.

The base line processing will produce a “fixed” or a “float” solution and it could be determined using L1 only or L1/L2. The fixed solution is considered best but for extremely long baselines the float solution may be the only solution available. For very short (3 miles and less) baseline, an “L1 Only” solution will probably be the final solution. However, users should hope for L1/L2 (also called iono-free) on baselines longer than approximately 3 or 6 miles.

The base line processing will generate several other quality indicators. The RMS error estimate of the vector is a good indicator - usually not more than 15 millimeters. A high ratio of difference between the two closest solutions of a baseline length indicates that the integer was easily established and so the result is more assured. Finally, the reference variance should be close to 1.00 – this is the ratio of the actual amount of error to the amount of error expected (given the accuracy in centering the antenna over the point and measuring the H.I.).

Performing loop closures on selected vectors will make blunders apparent. It may take a few tries to determine which vector is at fault. Just as with a conventional traverse, a ratio of precision or parts per million is the method of checking the closures.

A problematic baseline can be defined as a line observed with two carrier-phase GPS receivers, L1 or L1/L2, and the baseline solution does not meet the manufacturer’s specification for quality. In most cases, the problematic baseline was observed with enough satellites for a long enough time period, but the quality indicators show the line to be unacceptable.

The first thoughts may be to re-observe the line. However, this should be the user’s last resort. There are enough tools available in most baseline processing software to allow users to examine the observational information and detect obvious problems. Please refer to the manufacturer’s recommendations for troubleshooting problematic baselines.

NETWORK BASELINE

The Department recognizes there are arguments for and against the use of dependent (trivial) baselines in the least squares adjustment of a network. The Department recommends not using dependent baselines.

For any given multiple receiver session, there are n(n-1)/2 total vectors possible, where n = the number of GPS receivers observing simultaneously. The number of independent vectors is n-1. Using only the independent baselines:

- Prevents adjusting the same observations more than once and misstating the network degrees of freedom in the least squares adjustment
- Easier to troubleshoot and evaluate the network and locate deviant baselines.

ACCURACY STANDARDS FOR NETWORK BASELINES

For a station to qualify for an accuracy classification, network or local, it must meet the listed accuracy standards, relative to all other stations in the network and/or datum, whether or not there was a direct connection between them.

The “Figure 5-1 Minimum UDOT Network Design Specifications”, outlines requirements for network design.

FBN and CBN stations are statewide GPS survey networks that form the highest order of monumented control for the NSRS. These are A and B order points. NGS-maintained FBN stations at 62 miles station spacing and volunteer-densified CBN points at 16 – 31 miles spacing are included in the Figure 4-1 and serve as control for regional and local surveys.

Ideally, the time offset between observations should be 24 hours plus 3 – 9 hours before the second observation in order to “see” a completely different satellite constellation. A more practical approach for scheduling observations with a minimum of overlap is to remember that the satellite positions repeat about every 12 hours (actually they advance in position about four minutes a day). Scheduling with this information in mind could result in substantial savings in time and cost. Also, it should be noted that whenever possible, a different receiver should be used at that station for the repeat observation.

ADJUSTMENT

Once vectors have been processed, a least squares adjustment of the network will produce the best possible solution of final coordinates. The first adjustment should be minimally constrained by holding only one point to known coordinates. The results will indicate how well the GPS derived baselines fit together. If there had been a bad observation, it would show up here as an anomalous vector.

Then after ensuring that only good quality GPS baselines have been produced, the user can proceed holding each known reference station in subsequent iterations of the least squares process. By watching how remaining known points compare, the user will get an idea of how well the control points fit together. At this point, it can be seen how important it is to have additional control points as checks. The user may find that what was thought was a good control point might have to be thrown out. Once the chosen NSRS control for the project has been tested a fully constrained adjustment can be applied to obtain the final adjusted coordinates.

The user should be aware of standard least squares quality indicators. The final network should pass the chi-square test; the network reference factor should be about 1.00 (plus or minus .10) and the scalar will usually fall between about 5 and 10.
During the iteration process, two least squares statistics should be used to gauge progress:

- **Reference factor** – The reference factor shows how well the observations, along with their respective error estimates, are working together. Once the reference factor approaches 1.00, the errors in the observations are properly estimated and all observations have received their appropriate adjustments.

- **Chi-square test** – Typically when the reference factor approaches 1.00, the chi-square test of network error estimates, degrees of freedom, and level of confidence will pass. At this point, there is confidence that the network observations are working together and that there are no large errors remaining in the network.

MINIMALLY CONSTRAINED ADJUSTMENT

A minimally constrained adjustment is an adjustment with only one control point held fixed in the survey network. Holding one control point fixed, shifts observations to the correct location within the chosen datum. Not fixing a control point forces the software to perform a free adjustment. A free adjustment is accomplished by minimizing the size of the coordinate shift throughout the network. This equates to a mean coordinate shift of 0 (zero) in all dimensions.
A minimally constrained or free adjustment acts as one quality control check on the network. This adjustment helps to identify bad observations in the network. If an observation does not fit with the rest of the observations, it is highlighted as an outlier. The minimally constrained or free adjustment also checks on how well the observations hold together as a cohesive unit.
All minimally constrained adjustments must be performed in the WGS-84 datum. Since all GPS observations are made on the WGS-84 datum, the adjustment of the observations should be tied closely to the WGS-84 datum. Realistic error estimates for tribrach centering and H.I. measurement should also be factored into the minimally constrained adjustment.
Once the minimally constrained adjustment has been completed, move on to the fully constrained adjustment to fit the observations to the local control datum.

FULLY CONSTRAINED ADJUSTMENT

The fully constrained adjustment transforms the network of observations to the control points in the network. Once the network is fixed to those control points, adjusted coordinates based on the project datum (using the appropriate datum adjustment as recommended by the Department) for all other points in the network can then be determined.

Use this step to check that the existing control fits together well. The minimally constrained adjustment showed that the observations fit together and a fairly rigid network is defined. It is assumed that if any large errors are present in the fully constrained adjustment, the source is non-homogeneous control points (values). Any ill-fitting control points should not be fixed (constrained).

In the fully constrained adjustment, begin fixing the control values to determine how well the rigid network of observations fit the control. Essentially, the adjustment determines if the network of observations fit the network of fixed control points given some error estimate. These error estimates consist of the error estimates along with the applied scalar and set-up errors. The transformation parameters should then be calculated to allow the observations to fit to the control.

DETERMINING ELEVATIONS

After the fully constrained adjustment, the user will still only have heights measured from the ellipsoid (sometimes called GPS heights). It is necessary to determine orthometric elevations for use in the field. The use of a geoid model, such as GEOID12A, will usually yield orthometric elevations accurate to within a few centimeters in many places but for design survey accuracy it will be necessary to hold known elevations surrounding the project to get results within millimeters in relation to the surrounding marks.

From those ties, the geoid model is interpolated throughout the network to produce elevations on the newly surveyed points. Again, it can be seen why it is important to have more than just a couple of control points; vertical control points should be well spaced and surround the project whenever possible.

When processing the data, there are five (5) steps to follow for estimating GPS-derived orthometric heights:

- Perform a 3D minimally-constrained, least squares adjustment of the GPS survey project, i.e., constrain one latitude, one longitude, and one orthometric height value.
- Using the results from the adjustment in procedure 1 above, detect and remove all data outliers. The user should repeat procedures 1 and 2 until all data outliers are removed.
- Compute differences between the set of GPS-derived orthometric heights from the minimally constrained adjustment (using the latest National geoid model, e.g., GEOID12A) from the procedure above and the published NAVD 88 bench marks.
- Using the results from previous step above, determine which bench marks have valid NAVD 88 height values. This is the **most important step** of the procedure. Determining which bench marks have valid heights is critical to computing accurate GPS-derived orthometric heights. The user should include a few extra NAVD 88 bench marks in case some are inconsistent, i.e., are not valid NAVD 88 height values.
- Using the results from the previous step above, perform a fully constrained adjustment holding all valid known values fixed to arrive at the resulting elevations.

FIGURE 8-2 - GPS POSITIONING SPECIFICATIONS

Figure 8-2 Vertical GPS Survey Guidelines (Local Projects) 0.07 sft and 0.16 sft

SPECIFICATIONS	0.07 sft (20 mm)	0.16 sft (50 mm)
General		
Minimum number of horizontal control stations for the project (latitude, longitude, ellipsoid height)	3	3
Location of horizontal control stations relative to the center of the project; minimum number of quadrants, not less than	4 *(See Note 5)*	4 *(See Note 5)*
Location of vertical control stations relative to the center of the project; minimum number of quadrants, not less than	4	4
Maximum distance between project survey stations	6.2 Miles (avg. 4.3 Miles)	12.4 Miles (avg. 7.5 Miles)
Minimum percentageof all base lines contained in a loop	100%	100%
Minimum percentage of repeat independent base lines (adjacent station rule)	100% of total	100% of total
Field		
Dual frequency GPS receivers required	Yes	Yes
Maximum VDOP during station occupation	4	4
Minimum observation time per adjacent station base line	30 minutes	See Note 1
Minimum number of satellites observed simultaneously at all stations	5	5
Maximum epoch interval for data sampling	15 seconds	5 seconds
Time between repeat station observations	See Note 4	See Note 4
Minimum satellite mask angle above the horizon	15 Degrees	15 Degrees
Required number of receivers	3	3

SPECIFICATIONS	0.07 sft (20 mm)	0.16 sft (50 mm)
Office		
Antenna height measurements in feet and meters at beginning and end of each session	N/A	Yes See Note 2
Fixed integer solution required for all base lines	Yes	Yes
Ephemeris	Precise	Broadcast
Initial position: maximum 3-D position error for the initial station in any base line solution. See Note 3 below	33 feet	33 feet
Loop closure analysis, maximum number of base lines per loop	6	6
Maximum ellipsoid height difference for repeat base lines	0.07 ft	0.16 ft
Maximum RMS values of processed base lines	0.05 ft (typically <0.03 ft)	0.05 ft (typically <0.03 ft)

Notes:

1. Minimum time on adjacent station base lines must ensure that all intergers can be resolved and the root mean squatre error will not exceed 0.05 ft.

2. antenna height measurements are required at the beginning and end of each observation period and must be made in both feet and meters.

3. Start with HARN stations.

4. Complete the repeated observations on different days either four hours before the starting time of the first day's observations or four hours after the ending time of the first day's observations.

5. Three vertical control station (bench marks) determine the plane of the geoid but provide no redundancy. Include at least one additional vertical control station in the project to provide this redundancy. If possible, include three additional vertical control stations, especially in areas where there are changes in the slope of the terrain.

OPUS GPS SURVEYS

NGS OPUS (Online Positioning User Service) provides access to high-accuracy National Spatial Reference System (NSRS) coordinates. To process an OPUS position the user uploads a static data file collected with a survey-grade GPS receiver and obtains an NSRS position via email. For the Department, the primary applications of OPUS static would be to establish initial control in remote locations where CORS/NSRS stations are not readily available or to update coordinates of a passive mark. Another option would be to obtain an OPUS solution on a mark at either end of a project tied together by a terrestrial network. OPUS would not be used to establish the entire network because the points would have no direct baseline measured between them, therefore a least squares adjustment would have no direct baseline measured between them, therefore a least squares adjustment would not be possible. Visit the OPUS website for recommendations on establishing and accepting a quality mark.

Shared solutions within NGS OPUS provide an easy way to update the coordinates of a mark into the future. The service will automatically update the coordinates of the point as the NSRS changes realizations of NAD 83 through time. When uploading a 4hr+ GNSS data file to OPUS select "share my solution" and fill out the required details of the mark along with photos. NGS will store and update the coordinates of the mark through time and will use it to strengthen future models.
http://www.ngs.noaa.gov/OPUS/

OPUS PROJECTS

OPUS Projects is another online service provided through the NGS that allows baseline processing, least squares adjustment and publishing of multiple stations over multiple days. OPUS Projects was created to provide all users with NSRS three dimensional coordinate results for GNSS networks.

Solution reports contain coordinates for the observed project marks (monuments) as well as Continuously Operating Reference Stations (CORS) included in the project's processing. The project manager has the option to share the project by formally submitting via the bluebooking process in the NGS Integrated Database. OPUS Projects supports the bluebooking process by preparing output files (b-file, g-file, and serfil) for use with the bluebooking process and its key least squares adjustment program ADJUST.

Because of the complexity of the OPUS Projects service, access is limited to those who complete an OPUS Projects Manager's Training workshop. UDOT, UCLS, and Weber County have sponsored two OPUS Project Manager's Training workshops in 2014 and one in February of 2015. See the following link for additional information on OPUS Projects and future training workshops:
http://www.ngs.noaa.gov/OPUS-Projects/OpusProjects.shtml

GPS RTK SURVEYING

OVERVIEW

Real-time kinematic (RTK) positioning is similar to a total station radial survey. RTK does not require post processing of the data to obtain a position solution. This allows for real-time surveying in the field and allows the surveyor to check the quality of measurements without having to process the data.

RTK positioning may be used for Level 2 cm (0.066 sft) and 3-5 cm (0.098-0.164 sft) accuracy surveys as mentioned in Table 3-1 of this chapter. Level 2 cm (0.066 sft) accuracy surveys require that a second base station be set up for the purpose of creating a second baseline. Trimble units (and most others) will allow the averaging or adjustment of the two or more baselines while still standing at the point. Level 3-5 cm (0.098-0.164 sft) accuracy surveys will accept the single radial baseline solution. The surveyor must also follow the manufacturer's prescribed methods. Real-time surveying technology may utilize single or dual-frequency (L1/L2) techniques for initialization, but the subsequent RTK survey is accomplished using only the L1 carrier phase frequency. Therefore, all RTK surveys are currently subject to the limitations of the L1 frequency which is 10 kilometers (6 miles) from the base station. In order to maintain a 2 cm (0.066 sft) level of accuracy, distances are usually considerably less than this but there may be circumstances where this maximum range may be extended.

PLANNING

As with static GPS surveying, mission planning is an important step in performing a RTK survey. There are times of the day when the numbers of satellites available will vary. The positions of the satellites at various times of the day are also a factor. Planning your work around these times greatly increases productivity and the quality of your results. Most, if not all, software packages include utilities allowing users to predict satellite coverage.

The selection of the base station sites will also affect the success of the RTK observations. Users who select a poor base stations site will likely have problems throughout the entire survey. Select a site with good sky visibility down to 10 or 15 degrees from the horizon. Be aware of high power transmitters such as microwave, TV stations, military installations, high voltage transmission power lines, etc.

Multi-path may be caused by radio wave reflective objects such as trees, buildings, large sign-boards, chain link fences, etc. Because of the orbits of the satellites, obstacles to the north of the antenna setup are not as detrimental to reception.

It is worth the effort to get the base stations in optimum locations. A problem at the base is a problem at all rovers. A problem at one rover is only a problem at that one rover.

If possible, users should take part in the selection of any project control points in the beginning stages of a project. This is to insure that the points can be surveyed with GPS and well spaced for project coverage of real-time kinematic (RTK), if GPS is likely to be used. Of course, the primary project control points selected should always be GPS friendly.

SETTING UP THE BASE STATION

Set the base station at one second collection rate and at 13 degrees elevation mask. It is advisable to use a fixed height tripod (usually 2-meters). It is possible to do the entire survey without ever having to make an H.I. measurement – a considerable advantage over the conventional survey. It is strongly recommended that base stations be set up on known control points based on a geodetic datum within the project.

Most manufacturers provide options of starting an RTK survey with an autonomous position for the base (“here” option). Then after post-processing the data to establish correct coordinates, users can apply the corrected coordinates to edit the base station positions and shift the collected RTK data to its proper positions. A similar option is to start your base station with an autonomous (here) position but then observe control points and calibrate or localize (manufactures use different terms) to shift the data to the existing control values.

There are drawbacks to using these two approaches. The problems arise from the inaccuracy of the position of the base stations. For each ten meters of error in the base position, introduce an additional 1ppm (1mm per kilometer) error in our baselines. (This rule holds true with all GPS surveying techniques users might choose.)

Even after the base station data is post-processed and the coordinates are determined and shifted, error will remain in the baselines if the 10 meter fault is present. The finding of an autonomous position of more than 10 meters error, especially if baselines of more than a few kilometers were used, may mean a redo of the survey. For this reason, it is strongly recommended that base stations be known control points.

Using an unknown position for the base station in the methods described above is a poor substitute for the practice of occupying a known position.

THE ROVER

Set the rover receiver at one (1) second collection rate and 15 degrees elevation mask. The rover rod should always be a fixed height. Unlike conventional surveying from a total station, line of sight is not needed – there is no need to raise or lower the rod height. Usually a 2-meter rod is used. Not having to make this measurement eliminates one more chance of error.

Before getting too far away from the base station, check the radio (or cell phone) link to the rover. The first thing that must be done upon “starting the survey” on the data collector is to initialize the system (resolve the integer ambiguity). Several methods that are acceptable when preformed properly.

To avoid the possibility of an undetected incorrect initialization use one of the following methods to check the system.

After the first initialization, observe a point, this can be a temporary mark or a point in the survey. Discard the first initialization and re-initialize. After the new initialization has been accomplished return to the point being used as a check and re-shoot. Compare the first and second shots to within an acceptable tolerance. If the points check, proceed with data collection with the confidence of surveying with a correct initialization.

If the error between the two points is beyond the expected error one or both of the initializations used for a check are incorrect. The user must continue these steps until enough information is provided to identify the initialization that is incorrect. Once the problem is solved, users can begin the survey. This procedure must be repeated with any loss of initialization.

As with any surveying techniques the user would want to check a known point in the survey before beginning work, and at the end of the day before putting away the instrument, apply the same logic to your RTK survey.

The user is now ready to observe points. The amount of time of occupation will vary depending on conditions such as obstruction, multi-path, noise, etc. The user may have to resort to:

- increasing occupation time to a couple of minutes at one second epochs
- a more stable setup (use of a tripod or bipod)
- use of a ground plane when in a multi-path environment

A good rule of thumb is to reoccupy about 25% of all points requiring a Level 2 cm (0.066 sft) accuracy survey, after a new initialization or about 10% of the points in a topo survey.
Upon successful completion of the user’s observations, the user will now have a radial survey. Users must move the base station to a second control point and repeat the process for surveys that will not allow single baseline solutions (Level 2 cm (0.066 sft) accuracy surveys).
If radial lines are permitted, such as on a topographical survey or non-critical layout, it is still a good idea to occupy a second base station if another control point is nearby to randomly check a few of the points already established.

POST PROCESSING

An alternative method of performing a kinematic survey is to collect the data and process it at a later time. This does not require the use of a communications link (i.e. radio or cell phone) and can be combined with RTK to perform infill when the link is temporarily down. Post processed kinematic survey methods provide the surveyor with a technique for high production measurements and can be used in areas with minimal obstructions of the satellites.

PPK uses significantly reduced observation times (i.e. 0.5 to 3 minutes, usually 10-30 seconds per point) compared to static or fast-static/rapid-static observations. This method requires a least squares adjustment or other multiple baseline statistical analysis capable of producing a weighted mean average of the observations. Post processing will allow kinematic surveying to be used for some Level 2 cm (0.066 sft) accuracy surveys.

USING NETWORKED RTK (VRS)

Networked RTK is a new variation of RTK data collection. Rather than setting up a base station on the project, a number of permanent and continuously operating base stations are set up at about a 30 - 40 mile spacing, providing that augmentation to the basic position is determined at the rover.

These stations send GPS data into a central computer that streams the correction data to the Internet. The data can then be accessed by way of a cell phone/cell modem at the rover receiver. The data collector then uses this information to provide real time solutions with the same speed and accuracy as Base Station RTK but without the complication of setting up a receiver and radio on a local control point.

This system yields the same accuracies as the normally accepted three (3) miles of a standard radio-linked base station and rover. The AGRC has installed a number of these RTK networks. Coverage is growing across the state but presently covers the major metropolitan areas and some of the rural districts. Refer to http://gis.utah.gov/data/sgid-cadastre/turn-gps/.

The name virtual reference station (VRS) was coined for this method because a "virtual" base station point is determined by the computer from the network of base stations. The virtual base station is never more than 3 miles from the rover and is automatically redefined when the rover goes beyond that preset distance.

The AGRC TURN RTK Network uses the VRS technology. A virtual base point near the project is computed by the central computer. The user operating a rover unit dials in to the IP address for connection to the system. The data-ready cell phone/modem must then be physically carried by the user to maintain constant communication between the rover and the Internet. For information about this and other features that vary from place to place and time to time, contact your district survey coordinator, who in turn, may contact the administrators of the system at AGRC. Specific cell phone services and connection information should be obtained from the local cell phone service provider.

The same procedures and precautions as outlined for Base Station RTK should be followed using the AGRC TURN RTK networks. The difference is simply that users are not working from a base station set up by the user for a particular project. Users will not need to occupy the known station with a GPS receiver transmitting correction data to the rover(s). The work will be accomplished from a network of GPS base receivers.

In the case of a Level 2 cm (0.066 sft) accuracy survey point, where users would normally occupy a point more than once and from two or more base stations; three to six RRP's are already being used in the coordinate calculation using the networks. The point should still be occupied twice at different times of the day.

The AGRC TURN RTK Network is based on the National Spatial Reference System, which means that all coordinates are in the NAD83 datum and accuracy and compatibility should not be a problem. This however, can work against users when all previous work was done on local coordinates or the area of previous control may carry local biases.

To overcome the clash of coordinate values, the process of "calibrating" to the existing control is used. This was not used as extensively via the base station method where the control point coordinates were the start of subsequent GPS work.

Most RTK network surveys should be done after a calibration to existing control. Even if the horizontal component doesn't require a calibration, consider performing the vertical calibration. GPS solutions require the aid of a geoid model for elevations. In several areas around the state, the geoid model has an estimated difference of more than twenty eight hundredths of a foot from known elevations. If any known bench marks exist in the area; calibrate to them.

FIGURE 8-3A - THIRD ORDER (HORIZONTAL) GPS SURVEY

Figure 8-3 Third Order(Horizontal) GPS Survey Specifications

SPECIFICATIONS	STATIC	FAST-STATIC	KINEMATIC	RTK
General Network Design				
Minimum number of reference stations to control the project	3 Secondary (Horizontal) or better	3 Secondary (Horizontal) or better	3 Secondary (Horizontal) or better	3 Secondary (Horizontal) or better
Maximum distance between the survey project boundary and network control stations	9 Miles	6 Miles	6 Miles	6 Miles
Location of reference network control relative to the center of the project; minimum number of quadrants, not less than	3	3	3	4 + Center Point
Minimum percentage of all base lines contained in a loop	100%	100%	100%	0%
Direct connection between survey stations which are less than 20 percent of the distnace between those stations traced along existing or new connections (adjacent Station rule)	Yes	Yes	Yes	Yes
Minimum percentage of repeat independent base lines	100%	100%	100%	100% Antenna dump
Percent of stations occupied two or more times	100%	100%	100%	100%
Direct connection between intervisable azimuth pairs	Yes	Yes	Yes	No
Field				
Minimum PDOP during station occupation	5	5	5	5
Minimum observation time on station	70 Minutes	10 Minutes	5 Epochs	30 Epochs
Minimum number of satelites observed simultaneously at all stations	4	4	5 (100% of the time)	5 (100% of the time)
Maximum epoch interval for data sampling	15 seconds	15 seconds	1-15 seconds	1 seconds
Minimum time between repeat station observations	20 minutes	20 minutes	45 minutes	After antenna dump
Antenna height measurement in feet and meters at beginning and end of each session	Yes	Yes	Yes	Yes
Minimum satellite mask angle above the horizon	10 Degrees	10 Degrees	10 Degrees	10 Degrees

FIGURE 8-3A (Continued) - THIRD ORDER (HORIZONTAL) GPS SURVEY

SPECIFICATIONS	STATIC	FAST-STATIC	KINEMATIC	RTK
Office				
Fixed integer solution required for all baselines	Yes	Yes	Yes	Yes
Ephemeris	Broadcast	Broadcast	Broadcast	Broadcast
Initial position: Maximum 3-d position error for the initial station in any baseline solution	330 feet	330 feet	330 feet	N/A
Maximum misclosures per loop, in any one component (x, y, z) in a properly-weighted, least squares adjustment	0.16 feet	0.16 feet	0.16 feet	0.16 feet
Maximum allowable residual in any one component (x, y, z) in a properly-weighted, least squares adjustment	0.33 feet	0.33 feet	0.33 feet	N/A

Notes:

1. Network independent base lines are required to existing primary (or better) GPS established NSRS stations within 3.1 Miles of the project exterior boundary.
2. During office processing, start with a 15 degree mask. If necessary, the angle may be lowered to 10 degrees.
3. Precise ephemeris may be used.

FIGURE 8-4A - GENERAL ORDER (HORIZONTAL) GPS SURVEY SPECIFICATIONS

Figure 8-4A General Order (Horizontal) GPS Survey Speciofications

SPECIFICATIONS	STATIC	FAST-STATIC	KINEMATIC	RTK
Minimum number of reference stations to control the project	N/A	N/A	3 Third or better	3 Third or better
Minimum number of check stations	N/A	N/A	2	2
Maximum distance between the survey project boundary and the network reference control stations	N/A	N/A	6 Miles	Within project boundary/radio range/ 6 miles max.
Maximum PDOP during station occupation	N/A	N/A	5	5
Minimum observation time on station	N/A	N/A	5 epochs	As indicated by the system
Minimum number of satellites observed simultaneously at all stations	N/A	N/A	5 (100% of the time)	5 (100% of the time)
Maximum epoch interval for data sampling	N/A	N/A	1-15 seconds	1 second
Minimum satellite mask angle above the horizon	N/A	N/A	10 degrees *(See Note 1)*	10 degrees *(See Note 1)*

Notes:

1. During office processing, start with a 15 degree mask. If necessary, the angle may be lowered to 10 degrees.

CHAPTER 9: TOTAL STATION SYSTEM SURVEY SPECIFICATION

GENERAL

Survey specifications describe the methods and procedures needed to attain the desired survey standard. Specifications in the section are based on Federal Geodetic Control Subcommittee (FGCS) standards and specifications. Except where noted, they have been modified to give results that will meet the standards for various TSS surveys typically performed by the Department. For complete standards, refer to Chapter 4, “Accuracy Classifications and Standards”.

Department TSS survey specifications are to be used for all Department involved transportation improvement projects, including special-funded projects.

THE TOTAL STATION SYSTEM METHOD

The TSS is a system that includes an electronic total station and electronic data collecting system. Conventional survey methods of traverse, network, resection, multiple ties and trigonometric leveling are used with the TSS method. Each Department field survey crew is equipped with a TSS. The basic specifications for the Department TSS are:

- Angle measurement: 6” accuracy, (Standard deviation = 1”) Distance measurement: +/- (0.01 ft (3 mm) + 3 ppm) in standard mode
- Data Controller: Department standard data controller and with software compatible with Department’s design and survey software.
- PC Software: Department’s current supported software the system also includes tripods, tribrachs, prisms, targets and prism poles. For specific questions about the use of the software, see the programs Manual available

All TSS equipment must be properly maintained and regularly checked for accuracy.

REDUNDANCY

When proper procedures are followed, the Department TSS generally can easily meet the accuracy standards for Department second order, third order and general order surveys. For example, the Department TSS instrument specifications indicate that angles observed one time will meet the required accuracy standards, but without redundancy of observations, the possibility of blunders exist. For this reason, a complete set of angles is observed (two pointings to the backsight and two pointings to the foresight, minimum) whenever establishing or tying existing critical points such as control points and cadastral points. Redundant observations such as multiple ties are observed, whenever feasible, to improve the information available from least squares adjustments to strengthen survey networks.

EQUIPMENT CHECKS

Check total station vertical index and horizontal collimation each day.
Systematic errors due to poorly maintained equipment must be eliminated to ensure valid survey adjustments. Regularly check and adjust optical plummets, tribrachs, tripods, and leveling bubbles. For barometers and thermometers, check regularly for accuracy.

SET UP

- **Height of instrument and target:** Measure and enter the H.I. and H.T. into the data controller at the beginning of each set up. It is advisable to check the target and instrument heights at the completion of each set up along with the optical plummet's position over the point.
- **Temperature and barometric pressure:** Measure and enter the appropriate parts per million (ppm) correction into the data controller before work each day for general order and third order surveys. For second order surveys, make temperature and pressure readings and enter ppm correction into the data controller again at midday. Each 34°F (1°C) change in temperature will cause a one-ppm error, if the ppm setting in the data controller is not changed.
- **Checking:** After setting the instrument up, measure the distance to the backsight to provide a check. Observations of other known points are encouraged whenever practical. For general order surveys, it is good practice to observe selected points from two setups as a check. At the conclusion of each setup, re-observe the direction to the backsight. For general order surveys (construction staking, topographic surveys, etc.), where areas are surveyed from two different setups, have common points from the two setups to provide additional checks.
- **Mode:** All distance observations for second order and third order surveys are taken in standard measurement mode on the total station. Distances for general order surveys may be taken in track mode.

FIELD NOTES

Original survey notes, for all TSS observations, are maintained in the data controller and are stored electronically. Data controller headers must be completely filled in. Add comments about observations that might affect data reduction to the data controller file with a text entry. Data for all points that will be used as control and any cadastral monuments must be collected with 2 pointings in the data controller to be incorporated into a least squares adjustment.

SURVEY ADJUSTMENTS

All control points used for data gathering and stake out, including photo control, are adjusted by the method of least squares. Control points established by resection methods are adjusted for horizontal position by least squares before they are used in the field.
Second Order Surveys

APPLICATIONS

REGIONAL CONTROL:
TSS can be used to perform second order trigonometric leveling surveys for Regional Control Surveys.
PROJECT CONTROL: TSS can be used for horizontal and vertical Project Control Surveys to densify project control established by GPS.

HORIZONTAL SPECIFICATIONS

Method: Traverse with cross ties. Figure 9-1 lists the specifications required to achieve second order horizontal accuracy.

FIGURE 9-1 - SECOND ORDER (HORIZONTAL) TSS SURVEY SPECIFICATIONS

Figure 9-1 Second Order (Horizontal) TSS Survey Specifications

OPERATION/SPECIFICATION	TRAVERSE/NETWORK Horizontal
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Begin and end of each setup
Use plummet to check position over point for instrument and target	Begin and end of each setup
Measure temperature and pressure and enter ppm correction into total station	First setup and mid-day setup
Measure distance to backsight and foresight at each setup	Required
Observe traverse multiple ties to improve least squares adjustment	Required, as feasible
Close all traverses	Required
Horizontal angle observations	3 Direct, 3 Reversed (2 set) minimum
Vertical angle observations	3 Direct, 3 Reversed (2 set) minimum
Angular rejection limit, residual not to exceed	5"
Minimum measurement distance	330 feet

VERTICAL SPECIFICATIONS

Method: Trigonometric Leveling, a method by which differences in elevation are determined by measuring vertical angles and slope distances.

Trig leveling is a separate and different procedure than carrying elevations with conventional total station traversing. The total station is setup anywhere convenient just like a level and there is no measure up at the instrument. There is no requirement for balanced sight lengths, and differences in elevation of 60 feet or more between backsight and foresight in one setup are not uncommon in steep terrain. The key to success is redundant elevation differences to fixed height targets.

Figure 9-2 lists the specifications required to achieve second order vertical accuracy.

FIGURE 9-2 - SECOND ORDER (VERTICAL) TSS SURVEY SPECIFICATIONS

Figure 9-2 Second Order (Vertical) TSS Survey Specifications

OPERATION/SPECIFICATION	TRIGONOMETRIC LEVELING
Check vertical index error	4 times per day
Use fixed height staff for target	Required
Measure temperature and pressure - enter ppm correction into instrument	First setup, mid-day setup
Vertical observations - minimum	2 Direct, 2 Reverse, 2 sets *(See Note)*
Angular rejection limit, reject if difference from mean of observation exceeds	10"
Measure uncorrected zenith (elevation) difference	Each point
Measure uncorrected slope distance	Each point
Difference between two differences in elevation for each setup - not to exceed	0.005 feet
Maximum sight distance	700 feet
Minimum ground clearance line of sight	3 feet

Notes: Two sets of observations, each set yeilds an independent difference in elevation between the backsight and foresight.

THIRD ORDER SURVEYS

TSS can be used for both third order horizontal and vertical positioning.
Applications

- Supplemental control surveys for construction and engineering surveys
- Photogrammetric control
- Cadastral Location control
- Monumentation control
- Major structure and interchange staking

Supplemental control points are points that will be used as setup points to gather topographic data, locate monuments, perform Construction Staking and set out other control and right of way monuments.

SPECIFICATIONS

METHODS

- Traverse
- Resection: This method locates the unknown position of a setup point by observing known positions from the unknown point. Generally, points are re sectioned by observing three known points of equal or greater accuracy. Two point resections may be acceptable if the angle between the observed points is less than 135 degrees or greater than 225 degrees. All specifications for third order must be met. Figure 9-3 lists the specifications required to achieve third order accuracy.

FIGURE 9-3 - THIRD ORDER AND GENERAL ORDER TSS SPECIFICATIONS

Table 9-3 Third Order and General Order TSS Survey Specifications

OPERATION/SPECIFICATION	TRAVERSE/NETWORK Third Order	TRAVERSE/NETWORK General Order
Check vetical index error	Daily	Daily
Check horizontal collimation	Daily	Daily
Measure instument height and target height	Begin and end of each setup	Yes
Use plummet to check position over point for instument and target	Begin and end of each setup	Begin and end of each setup
Measure temperature and pressure and enter ppm correction into total station	First setup of each day	First setup of each day
Measure distance to backsight and foresight at each setup	Required	N/A
Observe traverse multiple ties to improve least squares adjustment	As Feasible	N/A
Close all traverses	Required	N/A
Horizontal angle observations	2 Direct, 2 Reverse (1 set) minimum	1 Direct
Vertical angle observations	2 Direct, 2 Reverse (1 set) minimum	1 Direct
Angular rejection limit, residual not to exceed *(See Note 1)*	10"	N/A
Minimum measurement distance to meet horizontal accuracy standards	165 feet	65 feet
Maximum measurement distance to meet vertical accuracy standard	330 feet	500 feet

Note: 1 - Reject angle if difference compared to mean of observation is greater than 10".

GENERAL ORDER SURVEYS

Applications

- Engineering survey collected topographical data
- Construction survey, staked points
- GIS surveys
- Environmental surveys

Specifications

The radial survey method is used for all General Order surveys. Data for General Order points are gathered as radial observations in the data controller and are not available for least squares adjustment.

For construction staking, staked positions are rejected, when the difference between the “set” (observed) position and the theoretical design position exceeds the allowable tolerances. Engineering survey data points are checked by various means including reviewing the digital terrain model, reviewing digital terrain lines in profile, and redundant measurements to some points from more than one setup.

CHAPTER 10: DIFFERENTIAL LEVELING SURVEY SPECIFICATIONS

GENERAL

Survey specifications describe the methods and procedures needed to attain a desired survey standard. Specifications in this chapter are based on Federal Geodetic Control Subcommittee (FGCS) standards and specifications. Except where noted, they have been modified to give results that will meet the requirements for various types of differential leveling surveys typically performed by the Department. For details regarding standards, refer to "Accuracy Classifications and Standards."

Department differential leveling survey specifications are to be used for all Department-involved transportation improvement projects, including special-funded projects.

DIFFERENTIAL LEVELING METHOD

These specifications apply to the use of compensator-type engineer's levels and electronic digital/bar code leveling systems. Equipment to be used is specified under "Method" for each order of accuracy in this chapter.

- Specifications for trigonometric leveling are covered in Chapter 9, "Total Station System (TSS) Survey Specifications."
- Specifications for GPS derived elevations are covered in Chapter 8, "Global Positioning System (GPS) Survey Specifications."

All differential leveling equipment must be properly maintained and regularly checked for accuracy. Systematic errors due to poorly maintained equipment must be eliminated to ensure valid survey adjustments. Equipment acquisition, repair, adjustment, and maintenance are covered in the Chapter on "Survey Equipment."

GENERAL DIFFERENTIAL LEVELING SURVEY SPECIFICATIONS

SIGHT DISTANCES

Sight distances and the balance between foresights and backsights are critical to maintaining accuracy in differential leveling. When poor environmental conditions are encountered reduce the sight distances. Under normal conditions the sight distances specified in this chapter will produce surveys that meet Department accuracy standards for second-, third-, and general-order surveys.

TURNING POINTS

Set turning points (TP) in stable, protected locations. Spikes or large nails set in pavement; wooden stakes set in firm soil; and prominent points such as rock outcroppings or the top of concrete curbs may be used as turning points. If a turning point does not have a definite high point, provide a mark at the exact point of rod contact.

Do not remove turning points after use, but leave them in place to provide a check in the event of blunders or excessive misclosures. A solid, well defined turning point may be used as a temporary bench mark (TBM).

BENCHMARKS

Benchmarks are a series of permanent points of known elevation located within the limits of the project. Benchmarks are very important, since the gradeline, earthwork, structure work and drainage are all referenced to benchmarks for elevation.

Establish benchmarks with physical characteristics and quality commensurate with the order of the leveling survey. Use benchmarks of a stable, permanent nature; e.g., galvanized steel pipe; steel rod driven into a firm soil base; or poured in place concrete. A brass Department disk epoxied into a drill hole in rock or concrete is also acceptable. Stamp benchmarks with identifying information; date, point designation at a minimum.

Locate benchmarks where they will be conveniently and easily accessible. Whenever possible, locate benchmarks outside of construction areas, clear of traffic, and within a public right of way or easement. Allow for future changes in landscaping and overgrowth of trees and foliage. Space benchmarks as required by project conditions and convenience of operation, generally not to exceed 3000 ft (1 km) apart. Minimum spacing for benchmarks is normally 1000 ft (300 m). In hilly terrain, place a benchmark where there is a 50 ft (15 m) difference in elevation. Place benchmarks within 200 ft (60 m) and on both sides of structure sites. Prepare a written benchmark/station description for inclusion in the survey notes and in the benchmark summary report.

Benchmarks should be shown on the Monumentation Map or the Record of Surveys as a method of recording.

DIFFERENTIAL LEVELING SURVEY NOTES

Record rod readings, for single- or three-wire leveling operations using a compensator-type engineer’s level, in digital form on a hand-held programmable calculator, computer, or data collector. Such calculators must produce a hard copy of all readings, reductions, and adjustments. Hard copies of data collection, reduction, and adjustment calculations will be incorporated into, and become a permanent part of, the survey field notes. Field notes can be recorded by hand, but must be scanned to obtain electronic images of the notes.

Raw field data generated by an electronic digital/bar code leveling system will be translated into field book format by use of conversion software such as “DIGILEV Translation Program” or “STARPLUS Data Conversion Utility.”

ADJUSTMENT OF DIFFERENTIAL LEVELING SURVEYS

A straight-line interpolation process adjusts second- and third-order differential leveling surveys, when run as a single loop or section. Corrections for the closing error will be prorated to each benchmark and TP between the two controlling benchmarks.

When multiple leveling survey loops interconnect to form a network, such as in corridor or project control, points common to two or more loops will be adjusted by application of least-squares adjustment. See “Least Squares Adjustment” in Chapter 7, “Accuracy Classifications and Standards.”

SECOND-ORDER DIFFERENTIAL LEVELING SURVEYS

APPLICATION

Second-order leveling surveys are generally confined to extending vertical control data over long distances, and establishing and maintaining regional vertical control.

For second-order differential leveling specifications acceptable to the National Geodetic Survey, see *Standards and Specifications for Geodetic Control Networks* published by the Federal Geodetic Control Committee, September 1984.

EQUIPMENT

Differential leveling survey methods/equipment to achieve second-order standards are:

- Compensator-type (automatic) engineer’s level (three-wire observations) with an invar-tape yard rod or a suitable metric graduated invar-tape rod.
- Electronic digital/bar-code leveling system with one-piece invar rod.
- If matched rods are used they must be alternated (leapfrogged) between setups.

Second-Order Three-Wire Differential Leveling Surveys

INSTRUMENT CHECK

At the beginning and end of each day’s operation, check the instrument for collimation error (two-peg test), recording the tests into the survey notes. Description of the two-peg test can be found in any standard surveying text. If an error in excess of 0.007 ft (2 mm) within a 200 ft (60 m) sight distance is detected, readjust the level. Immediately check the instrument if it is severely jolted, bumped, or suspected as such. Check compensator-type instruments for proper mechanical operation at least every two weeks of use. See Section 3-03 Adjustment of Equipment for specific instructions on performing the two-peg test.

Limits of Sight Distances

Do not exceed sight distances of 230 ft (70 m). When more than two rod readings (see Rod Readings, below) are rejected in ten setups, reduce the sighting distance. Do not exceed 15 ft (5 m) for the difference in length between foresights and backsights of a single setup.

Rod Readings

Rod readings are estimated to the nearest 0.005 ft (1 mm). For each foresight and backsight reading of a set, the middle wire reading must be within 0.005 ft (1 mm) of the mean of all three wire readings. If this is not achieved, the misread or mis-recorded wire must be identified and corrected before moving to the next setup.

See Figure 10-1 for second-order, three-wire differential leveling standards and specifications. Second Order, Electronic Digital/Bar Code Leveling System.

Manufacturers specifications recommend that the electronic digital leveling instrument not be exposed to direct sunlight. Use umbrellas in bright sunlight. When using electronic digital leveling instruments, the absolute collimation error will be recorded along with the leveling data. See Figure 10-1 for second order electronic digital/bar code differential leveling standards and specifications.

FIGURE 10-1- SECOND-ORDER DIFFERENTIAL LEVELING SPECIFICATIONS

Figure 10-1 Second Order Differential Leveling Specifications

OPERATION/SPECIFICATION	COMPENSATOR-LEVEL Three - Wire Observations	ELECTRONIC/DIGITAL Bar Code Level
Difference in length between foresights and backsights, not to exceed per setup	16 feet	16 feet
Cummulative difference in length between foresights and backsights, not to exceed per loop or section	33 feet	33 feet
Maximum sight lengths	230 feet *(See Note 1)*	230 feet *(See Note 1)*
Minimum ground clearance of sight line	1.5 feet	1.5 feet
Maximum section misclosure	0.035 feet x (√D) *(See Note 2)*	0.035 feet x (√D) *(See Note 2)*
Maximum loop misclosure	0.035 feet x (√E) *(See Note 3)*	0.035 feet x (√E) *(See Note 3)*
Difference between top and bottom interval not to exceed	.20 of rod unit	N/A
Collimation (Two-Peg) Test	Daily (not to exceed 0.007 feet) *(See Note 4)*	Daily
Minimum number of readings. (Use repeat measure option for each observation)	N/A	3 *(See Note 5)*

Notes:

1. Leveling staff in backlit condition may decrease maximum sight distance
2. D = Shortest one-way length of section in miles (section is defined as a series of setups between two permanent control points).
3. E = Length of loop in miles (loop is defined as a series of setups closing on the starting point).
4. Readjust level if 0.003 feet in 200 feet is exceeded
5. If the standard error of the mean exceeds 0.003 feet, continue repeat measurement until the standard error of the mean is less than 0.0003 feet.

THIRD ORDER DIFFERENTIAL LEVELING SURVEYS

APPLICATIONS

Third-order leveling surveys are used to establish vertical control and maintain benchmarks for:

- Project Control
- Supplemental Control
- Photo Control
- Construction Survey Control
- Topographic Survey Control
- Major Structure Points

SPECIFICATIONS

METHODS

- Compensator-type engineer's level (three-wire method) and yard rod or metric graduated Philadelphia-style rod
- Compensator-type engineer's level (single-wire method) and metric graduated
- Philadelphia-style rod
- Electronic/digital level and bar-code rod (wood or noninvar metal) See Figure 10-2 for third-order differential leveling methods and specifications.

FIGURE 10-2- THIRD-ORDER DIFFERENTIAL LEVELING SPECIFICATIONS

Figure 10-2 Third Order Differential Leveling Specifications

OPERATION/SPECIFICATION	COMPENSATOR -LEVEL Three - Wire Observation	COMPENSATOR -LEVEL Single - Wire Observation	ELECTRONIC/DIGITAL Bar Code Level
Difference between foresights and backsights, not to exceed per setup	33 feet	33 feet	33 feet
Cumulative difference in length between foresights and backsights, not to exceed per loop or section	33 feet	33 feet	33 feet
Maximum sight length	300 feet	300 feet	300 feet
Minimum ground clearance of sight line	1.5 feet	1.5 feet	1.5 feet
Maximum section misclosure	0.05 feet x (√D) *(See Note 2)*	0.05 feet x (√D) *(See Note 2)*	0.035 feet x (√D) *(See Note 2)*
Maximum loop misclosure	0.05 feet x (√E) *(See Note 3)*	0.05 feet x (√E) *(See Note 3)*	0.035 feet x (√E) *(See Note 3)*
Difference between top and bottom interval not to exceed	.30 of rod unit	N/A	N/A
Collimation (Two-Peg) Test	Daily (not to exceed 0.007 feet) *(See Note 4)*	Daily	Daily
Minimum number of readings. (Use repeat measure option for each observation)	N/A	N/A	3 *(See Note 5)*

Notes:

1. Leveling staff in backlit condition may decrease maximum sight distance
2. D = Shortest one-way length of section in miles (section is defined as a series of setups between two permanent control points).
3. E = Length of loop in miles (loop is defined as a series of setups closing on the starting point).
4. Readjust level if 0.007 feet in 200 feet is exceeded
5. If the standard error of the mean exceeds 0.003 feet, continue repeat measurement until the standard error of the mean is less than 0.003 feet.

GENERAL ORDER DIFFERENTIAL LEVELING SURVEYS

The survey party chief determines appropriate procedures for Order G (General) differential leveling, based on the particular needs of the survey task being performed. When developing procedures consider the following: objective of task, specific needs of the project and most efficient use of time.

See Chapter 6, "Base Mapping Survey Procedures," and Chapter 7, "Construction Survey Procedures," for tolerances and accuracy standards for specific types of surveys.

APPLICATIONS

Order G leveling surveys are generally used to provide elevations for:

- Supplemental Design Surveys
- Construction Layout
- Environmental Surveys
- GIS Data Surveys
- Topographic Survey Data Capture

SPECIFICATIONS

Compensator-type engineer's level (single-wire method) methods:

- Philadelphia-style rod
- Lenker-style rod
- 25 foot extendible fiberglass rod

CHAPTER 11: LIDAR

FUNCTION AND PURPOSE OF LIDAR

LIDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the LiDAR system generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. Safety and efficiency of data collection are compelling reasons to use laser scanning. The ability to acquire a great deal of accurate measurements in a short time is tremendous, especially in areas that are not conducive to traditional methods of data collection. Scanning data needs to be registered and geo-referenced into a project point cloud. These clouds of points typically contain millions of points where a traditional survey may only have several hundreds of points. Some of the typical LiDAR applications include: pavement analysis surveys; roadway/pavement topographic surveys; structures and bridge clearance surveys; engineering topographic surveys; deformation and settlement monitoring surveys and as-built surveys.

Modern LiDAR Instruments fall into three relevant categories (static, mobile, and airborne) all of which are unique methods and depending on the nature of the project, can also be complimentary one to another. Factors such as: distance from the mapping object, required density or detail, perspective or point of view of the sensor, safety and efficiency, cost and value needed for the project; all of which should be taken into consideration in selecting the right type of LiDAR technology to be used. For instance a mobile scanning project may employ the use of a static based scanner to provide the needed structural components under a bridge.

Static LiDAR refers to laser scanning applications that are performed from a ground-based fixed point on the surface of the earth. The basic concept is similar to that of a total station. However, there are significant differences in the amount and speed of point data collected, field procedures, data processing and error sources. The point clouds collected from static scans typically yield very dense and highly detailed data not obtainable from other LiDAR Technologies.

Mobile LiDAR uses laser scanning technology in combination with GNSS, inertial measuring units (IMU) and other sensors to gather data from a moving vehicle. Mobile platforms may include SUV's, cars, trucks, rail vehicles, or boats. Best suited for surveys moderate to large in linear extent, data collection on 20 miles of highway per day is achievable by most systems. These vehicles often include imaging sensors such as hi-definition video or digital photography.

Airborne LiDAR, being somewhat of a hybrid between photogrammetry and mobile LiDAR, is generally best suited for surveys very large in geographic extent from a "birds eye" point of view. Usually installed on a manned or unmanned fixed wing aircraft or helicopter. Airborne LiDAR makes it possible to three-dimensionally map a large wide area in a single flight line.

Regardless of the LiDAR method of scanning used, all raw scans must be post-processed to create a Digital Terrain Model (DTM), extracted line work, points, break lines, and other base mapping features required by the Project Delivery Network.

CHAPTER 12: UNMANNED AIRCRAFT SYSTEMS (UAS)

UAS, which stands for Unmanned Aircraft Systems, is an aerial imaging solution specifically designed for surveyors and geospatial professionals.

Many surveying and mapping professionals across the world are successfully using UAS for their applications because it is:

- A highly economic solution that enables aerial mapping, once reserved for the largest surveying and engineering firms, to be used by the masses
- A safe solution that enables surveying of rugged, hazardous, hard-to-reach or unhealthy areas without risking injury
- An efficient tool giving the ability to collect and process data faster than traditional terrestrial-based surveying technology
- Designed to quickly plan a flight and collect data, allowing rapid response to your customer's needs
- And advanced technology that can easily be used to serve numerous professional markets and applications

UAS Aerial Imaging solutions are being used to perform boundary & topographic surveys, site & route planning, progress monitoring, as-builts, volume determination, vegetation health and disaster analysis. From a single flight, operators are able to generate feature maps, topographic contours, 3D surface models, orthophotographs, and Normalized Difference Vegetation Index (NDVI) maps for vegetation.

UAS is currently being used in Engineering and Surveying, Mining, Civil & Heavy Earthworks Construction, Oil & Gas, Environmental & Landfill, Public Agencies, and Agriculture & Forestry Industries.

Obtain Authorization from UDOT UAS Coordinator prior to any flight for UDOT Projects or on UDOT Right of Way.

All unmanned aircraft flights must follow Federal and state laws pertaining to UAS flights , UDOT UAS Policy, and UDOT UAS Procedures.

CHAPTER 13: EXISTING RIGHT OF WAY

Refer to requirements in the current [UDOT Right of Way Design Manual.]

CHAPTER 14: AERIAL & PHOTOGRAMMETRY

AERIAL PHOTOGRAPHY

GENERAL

The intent of the specifications, and proposal is to prescribe the details for performance and completion of the work which the consultant undertakes in accordance with the terms of the contract. Where the specifications and work task order describe portions of the work in general terms, but not in complete detail, it is understood that only materials and workmanship of the first quality are to be used. The consultant shall furnish all labor, materials, tools, equipment, and incidentals, and do all the work involved in executing the contract.

The Consultant shall have previous experience in the type of specialized aerial photography acquisition required in these specifications. The Consultant shall own or have available for use:

- A suitable airplane capable of a 20,000 foot operational altitude. The statement shall include the names of the pilot and photographer.

- A flight log representing aircraft flight time, heading, exposure locations (lat/long) and weather conditions shall be maintained on an hourly basis to the nearest 0.1 of an hour between the time of takeoff and the time of landing for the contract. The log shall be signed by the pilot or the aerial photographer and be submitted with each contract.

Aerial photographs shall be taken between the hours of 10:00 am and 2:00 PM local solar time, on days when well defined images can be obtained. Photographing shall not be attempted when the ground is obscured by haze, smoke or dust, snow or when clouds or cloud shadows will appear on more than five percent of the area of any one photograph. Photographs shall not contain shadows caused by topographic relief or sun angle, whenever such shadows can be avoided during the time of year the photography must be taken.

Ground conditions: The season and any special requirements concerning foliage, snow, or other conditions which might obscure ground detail may limit the seasons that photography may be taken. It shall be the responsibility of the consultant to schedule photography to avoid these conditions. However, if questions or concerns as to conditions exist, consultation with the project manager shall occur before undertaking or continuing the photographic operations.

The aircraft furnished shall be capable of stable performance shall be equipped with essential navigation and photographic instruments and accessories, with all maintained in operational condition during the photographic mission. No windows shall be interposed between the camera lens system and the terrain. Also, the camera lens system shall not be in the direct path of any exhaust gases or oil from aircraft engines.

Flight height: Departures from the specified flight height shall not exceed 2 percent low or 5 percent high for all flight heights up to 2,000 feet above ground elevation. Above 12,000 feet, departures from specified flight height shall not exceed 2 percent low or 600 feet higher.

Flight line Maps: Prior to executing the aerial flight, the Consultant shall provide a detailed flight plan for acquisition of aerial photography to the Department for approval. Planned flight lines can be delivered as shape files or as a Google Earth .KMZ file showing photo centers, photo coverage extents, proposed mapping extents, ground control locations, and flight heights.

- The flight height above the average elevation of the ground shall be such that the imagery has an average scale suitable for attaining the required photogrammetric measurement, map scale, contour interval and accuracy.

- Imagery having a departure from the specified scale of more than five percent because of tilt or any changes in the flying height shall be rejected.

- All of the area appearing on the first and last exposure of each flight line that crosses a project boundary shall be outside the boundary. Each strip of photographs along a project boundary shall extend over the boundary not less than 15 percent.

- End lap (overlap in the line of flight shall not exceed 65% nor be less than 55%**,** and shall average 60% plus or minus 2%**.** Sidelap (overlap of parallel strips of aerial photography) shall not exceed 40%**,** nor be less than 20% and shall average 30% plus or minus 5%**.** However, the Department reserves the right to specify end lap and/or sidelap for individual projects.

- Terrain Elevation Variances. When ground heights within the area of overlap vary by more than ten percent of the flying height a reasonable variation in the stated overlaps shall be permitted provided that the fore and aft overlap does not fall below fifty-five percent and the lateral side lap does not fall below ten percent or exceed twenty percent. In extreme terrain relief where the foregoing overlap conditions are impossible to maintain in straight and parallel flight lines, the gaps created by excessive relief shall be filled by short strips flown between the main flight lines and parallel to them.

- Crab. Any series of two or more consecutive photographs crabbed in excess of ten degrees as measured from the mean flight path of the airplane, as indicated by the principal points of the consecutive photographs, may be considered cause for rejection of the photographs. Average crab for any flight line shall not exceed five degrees. Relative crab in excess of ten degrees between two successive exposures shall be rejected. For aero triangulation, no photograph shall be crabbed in excess of five degrees as measured from the line of flight.

- Tilt. Imagery exposed with the optical axis of the aerial camera in a vertical position is desired. Tilt (angular departure of the aerial camera axis from a vertical line at the instant of exposure) in any frame of more than three degrees an average tilt of more than one degree for the entire project, an average of more than two degrees for any ten consecutive frames, or relative tilt between any two successive frames exceeding five degrees, shall be cause for rejection.

- The Department reserves the right to order the consultant to make reflights at his own expense whenever the aerial photography is rejected for failure to meet specifications.

- The selection of an appropriate contour interval is extremely site-dependent and will be indicated in the work task order or RFP. The following table shall be used to determine flight height for a given contour accuracy:

	Native GSD (100m lens)
1' Contour	4cm
2' Contour	8cm
5' Contour	16cm

AERIAL CAMERAS

FILM CAMERAS

The photographs to be used in precise photogrammetric work must be obtained through the use of a fully calibrated precision camera with a single high resolution low distortion lens. Cameras used for photogrammetric mapping must meet the requirements outlined below. The aerial camera used shall be equipped with forward motion compensation.

The camera shall have been calibrated by the U.S.Geological Survey, within the past 3 years.

- Type of Camera: A single lens precise aerial mapping camera equipped with a high resolution, distortion free lens shall be used. The camera shall function properly at the necessary altitude and under expected climatic conditions, and shall expose a 9-inch square negative. The lens cone shall be so constructed that the lens, focal plane at calibrated focal length, fiducial markers and marginal data markers comprise an integral unit or are otherwise fixed in rigid orientation with one another. Dimensional changes brought about by variations of temperature or other conditions shall not be of such magnitude as would cause deviation from the calibration focal length in excess of plus or minus 0.05 millimeter or would preclude a determination of the point of location to within plus or minus 0.003 millimeters.

- The calibration report shall be presented to the consultant manager prior to award. Certification shall also be provided indicating that preventative maintenance has been performed within the last two years. The camera features shall be as follows:
- The calibrated focal length of the lens shall be 153 millimeters, plus or minus 3 millimeters, and measured to nearest .001 millimeter.
- The focal plane surface of the platen shall be flat to within 0.013 millimeters and shall be truly normal to the optical axis of the lens. The camera shall be equipped with means of holding the film motionless and flat against the platen at the instant of exposure.
- The camera shall be equipped with a minimum of four fiducial marks, with eight preferably for accurately locating the principal point of the photograph. The lines joining opposite pairs of fiducial marks shall intersect at an angle within one minute of 90 degrees.

- The absolute value of radial distortion measured at maximum aperture, as stated in the calibration report, shall not exceed 0.01 millimeter. The tangential distortion shall not exceed 0.005 millimeters.

- With appropriate filter mounted in place, the Area Weighted Average Resolution shall be at least sixty lines/millimeter when measured on type V-F spectroscopic plates at maximum aperture stated on calibration report. The lens shall be fully corrected for color photography.

- An appropriate light filter with an antivignetting metallic coating shall be used. The two surfaces of the filter shall be parallel to within ten seconds of arc. The optical characteristics of the filter shall be such that its addition and use shall not cause any undesirable reduction in image resolution and shall not harmfully alter the optical characteristics of the camera lens.

- The camera shall be equipped with a between-the-lens shutter of the variable speed type, whose efficiency shall be at least eighty percent at the fastest rated speed.

- The deviation from flatness of the average data from two models (elevation discrepancy at photography scale) at measured points may not exceed plus or minus 1/8000 of the focal length of a nominal 6-inch (153 mm) focal length camera. If elevation discrepancies exceed this value, the camera will not be acceptable.

DIGITAL CAMERAS

Digital cameras must be tested and calibrated with manufacturer certification documentation. The camera must be geometrically stable and suitable for use in precise, high-accuracy photogrammetric orthoimagery applications. All delivered imagery shall be acquired and processed in such a way as to eliminate or minimize pixel or band offset or misalignment between bands. The camera shall provide the following:

- The camera shall provide the spatial resolution and field of view necessary to meet the ground sample distance (GSD) requirement as specified in the contract.

- Pan sharpening will be permitted to achieve the necessary spatial resolution requirements. The multi-spectral bands may be used at a ratio no greater than 1:5
- (multi-spectral to panchromatic) to achieve the required spatial resolution.

- The camera's sensor shall capture and record a minimum of 12-bits of image information per color channel. If more than one lens and more than one shutter are used in the camera, the difference in radiometric values between two panchromatic or two multi-spectral sensors shall be less than ±5%. For example, a 12-bit image shall not have more than ±205 difference in gray values.

- The camera shall capture, as a minimum, natural color (approximately 440 – 850 nm) and near infrared color (approximately 780 – 850 nm) channel data simultaneously or near simultaneously using a single camera (near simultaneously is defined as less than 500 milliseconds).

- The digital camera and its mount shall be checked for proper installation prior to each mission. An automatic exposure control device is permitted, but a manual override capability is required for some types of terrain to achieve proper coverage and exposure. The camera mount shall be regularly serviced and maintained and shall be insulated against aircraft vibration.

- The contractor shall perform all maintenance in accordance with the manufacturer's recommended and established procedures. The contractor shall maintain a complete history of all maintenance done to the camera system and have it available for Department inspection. The contractor shall provide certification that the system has been maintained, preventive maintenance and calibration performed, to the manufacturers requirements.

- Calibration reports for each digital camera proposed for use shall be submitted to the contracting officer with the contractor's proposal and prior to project imagery
- Acquisition if the digital camera is removed and remounted. The contractor shall follow manufacturer's specifications for appropriate calibration and recalibration. The calibration reports shall address the geometric performance of the camera, and at a minimum, include:

- Date of report
- The name of the person or company performing the calibration
- The methodology and procedures used for calibration
- Final calibration parameters, such as calibrated focal length, lens distortion values, radiometric calibration parameters, and principal point location.

NOTE: The Department recognizes that individual calibration reports, procedures, and parameters may be unique to a certain manufacturer since equipment and systems vary from manufacturer to manufacturer.

PHOTOGRAPHIC FILM

Only unexpired film of the type specified shall be used. All film shall be purchased by the consultant. All aerial film shall be of archival quality. The film exposed and processed shall not be spliced. The processed negatives shall be free of stains, discoloration, or brittleness that can be attributed to ageing.

TYPES OF AERIAL FILM

The Consultant shall furnish aerial film of a quality that is equal to or superior to 4 mil Kodak Double-X Aerographic 2405 (Estar Base) panchromatic film,: 4 mil Kodak Plus Aerographic 2402 panchromatic (Estar Base) film: 4 mil Kodak Infrared Aerographic 2424 film; 4 mil Kodak Aerochrome Infrared 2443 film (estar Base). Only fresh, fine grain, dimensionally stable, and safety base aerial film shall be used.
Color infrared (CIR) emulsion shall be sensitive to the visible and near infrared spectrum from 400 to 900 nanometers. The film shall be a polyester base with a nominal thickness of 0.8 mils and shall have three gelatine layers containing silver halide, one layer to be sensitive to infrared light, one to be sensitive to green light, and the other to be sensitive to red light.

Black-and white emulsion shall be sensitive to red, green, and blue wave lengths.

All aerial film shall be processed under controlled conditions in automatic, continuous-film processors. The film shall be processed in accordance with the manufacturer’s instruction. The processing, including development and fixation, and washing and drying of all exposed photographic film, shall result in negatives free from chemical or other stains, containing normal and uniform density, and fine-grain quality. Before, during and after processing, the film shall not be rolled tightly on drums or in any way stretched, distorted, scratched, or marked, and shall be free from finger marks, dirt, or blemishes of any kind.

PHOTOGRAMMETRIC MAPPING

GENERAL

The work to be done consists of furnishing topographic maps, with a specified contour interval supplemented with spot elevations, at a specified scale, as described in the work task order or RFP. The work to be done will require the Consultant to furnish the topographic field control data, aerial photography and materials necessary for finishing the topographic maps.

CONTOUR AND PLANIMETRIC MAPS

PLOTTERS

The work to be done will be planned for a precision stereoscopic plotter. The type of stereoscopic plotter instruments and any interfaced plotting equipment (such as automatic plotting tables or CADD related, in line, hardware) that will be used by the consultant is to be submitted to the Department for approval before award of the Contract to the Consultant.

The photo scales and the attendant map scale (compilation scale) to be used by the Consultant shall be submitted to the Department for Approval before award of the Contract to the Consultant.

The “c” factors to be used by the Consultant for “softcopy” work stations or first order analytical instruments shall not exceed 1500.

DATUM

The North American Datum of 1983 (NAD 83) in meters will be used for all mapping projects except when matching or extending existing mapping based on North American Datum of 1927 (NAD 27). Unless specified, all mapping shall be placed on a ground datum utilizing State Plane Coordinate Grid Adjustment Factors.

The final map shall show all grid ticks as well as horizontal and vertical control. It shall be the responsibility of the Consultant to document control in conformance with these specifications.

The maps shall be compiled at the scale and contour interval specified in the work task order or RFP.
The mapping limits and the numbering, dimensions, and orientation of the final maps shall be as specified in work task order, RFP, or as directed by consultant manager.

Adjacent map files shall butt match exactly. Match lines shall be delineated and labeled as prescribed in the UDOT ”CADD Standards”.

Where the meaning of symbols is obscured by adjacent topography, the object shall be labeled.

Where the symbols shown do not properly describe a planimetric feature, the Consultant shall select an appropriate symbol and label the feature.

Labels shall be oriented along linear features or parallel to the flight line of the stereo model being compiled, so that project beginning shall be at the left and project end shall be at the right.

DIGITAL PHOTOGRAMMETRIC STEREO COMPILATION

In order that the maps be compatible with the Department CADD System, the following requirements must be met:

Maps produced on a CADD system by the Consultant shall conform to UDOT’s current CADD standards. This includes levels, line codes, line weights, line color, symbols, and text.

The data files provided by the Consultant shall be intergraph vector files which can be manipulated in Bentley’s MicroStation software. Raster image files will be submitted in TIFF and HMR formats.

All files provided by the Consultant shall be delivered on DVDs, portable flash drives, or uploaded into the Department ProjectWise System with proper attributes.

Use of reference files or pen tables to achieve particular plotted effects is not allowed, each file must stand on its own.

Each file shall contain map features for one or more stereo models. Individual stereo models shall not be separated into more than one file regardless of size. Files shall be merged so as to contain approximately 1500 blocks but should be limited in size not to exceed 72” in length when plotted at final map scale.

The name of the design file must appear in the lower left corner of the final plotted map sheet. Each file shall be numbered using a four digit number, followed by a one letter designation for the flight line number, followed by a four digit number representing the first and last photo numbers representing the first and last photo numbers of the stereo models in the file. (Example) 2771E908.

Files shall be compiled with coordinate values to the nearest thousandth (1/1000) of a foot. Coordinate values for all features shall be based on the grid system indicated by the control data. The working units for design files shall be:

Master Units 1 US Survey Feet: Sub Units =US Survey Inches (1/12 Foot): Positional Units = 1000 (1/10000 Foot).

The global origin shall be set such that the working units origin (0.0) shall be at the center of the design plane.

All digital data shall be recorded directly as a function to the stereo plotter operation. Post compilation digitizing of graphic compilation is not acceptable. Contours shall be generated from surface point files.

CONTENTS OF MAPS

All map features shall be as prescribed in the UDOT "CADD Standards"
The completed maps shall show horizontal control monuments, bench marks, section corners, city street monuments, right-of-way monuments, contours, grid system, and all topographic and planimetric features shown in the "CADD Standards."

MONUMENTS, BENCH MARKS AND GRID SYSTEM

Grids shall be shown with 1/2-inch long grid cross-ticks spaced at five-inch intervals at final map scale. Grids shall be labeled around the perimeter of the map. Grids on adjacent maps shall be a continuation of the five-inch intervals. Intermediate grid intervals shall be used when necessary to fulfill this requirement. Any such intermediate grids need not be labeled.

Grid coordinate values shall be designated X and Y.

TOPOGRAPHIC FEATURES

The Project Manager shall specify the required contour interval. Every fifth contour shall be of heavier weight. Care shall be exercised in labeling contours to the end that the elevation of any contour is readily discernible. Contour designations shall not be abbreviated. All digits shall be shown on the contour maps.

Labels shall be orientated to follow the contours and be readable from the same direction as other text. The distance along a contour between labels shall not exceed five inches at map scale. There shall be a break in the contour wide enough to allow placement of the contour label. Where possible, contour labels shall be in diagonal stacks one above another along the line of the slope.

All contours shall be continuous.

In areas of comparatively level terrain where contours are more than five centimeters apart at final map scale, the contours shall be supplemented by spot elevations spaced one inch apart at final map scale in each direction to form a rectangular grid, parallel to the center of the mapping area. In built-up areas where trees or buildings preclude exact adherence to a grid pattern, the pattern may be varied but the density and spacing of spot elevations shall not be less than that of the grid pattern.

Where the profile gradient is 2 percent of less, spot elevations shall be shown at intervals not greater than two inches at final map scale, along the center of dikes, roads, ditches, and railroads. Spot elevations shall be shown at all sags and crests regardless of gradient. The spot elevations for roads and railroads crossing highways will be field supplied.

Spot elevation shall be shown at intervals not exceeding two inches at final map scale, along the boundary of the area to be mapped at locations where the nearest contour is over one inch from the boundary.

Where interpolation of the contours will not show correct elevations, such as summits, depressions, saddles, and road intersections, spot elevations shall be shown.

All spot elevations shall be labeled with decimal values giving their elevation to three significant figures rounded to the nearest one-tenth of a foot. Labels shall be placed parallel to the flight line and positioned so that they do not obscure other map features.
When the digital terrain model is produced photogrammetrically, and where areas of structure, brush, or tree cover obscure the ground so that the digital terrain model cannot be measured completely and accurately from the photographs, the data necessary to complete the work shall be secured by ground surveys.

When the map is to be used for rehabilitation or reconstruction where the new pavement is to be placed immediately on top of the existing pavement, the spot elevations for center of road, curb and gutter, edge of road, and utility locations shall be obtained by field procedures as noted previously.

PLANIMETRIC FEATURES

All planimetric features which are visible or identifiable on, or are interpretable from the aerial photography shall be shown. Particular attention shall be given to include drainage features, fences, walls, and other indications of property lines or lines of occupation. The field data locating utilities will be used to supplement those noted from aerial photography.

The maps shall show all roads, railroads, bridges, canals, streams, dams, fence lines, wells, power and telephone poles, billboards, highway signing, and highway culverts, which are visible on the aerial photographs, or were obtained from field means. They shall also show boundaries of timber and brush areas, slide and slip out areas, orchards, vineyards, and any other improvements or distinguishing features which are visible on the aerial photographs.

Orchards planted in regular rows may be symbolized by a dot for each tree, except for the outer rows which shall be shown by appropriate symbol. Free standing trees having a crown diameter of 15 feet or more shall be shown.

All schools, parks, playgrounds, cemeteries, public buildings, hospitals, churches, institutions, and similar places of public gatherings shall be shown and labeled. Published information may be used as a source for this data and field inspection or verification will not be required.

Roadway lane striping if visible or obtained by field data shall be delineated by appropriate symbol.

Drainage lines shall be shown in all well-defined drainage features indicated by the contours where the drainage is over 500 feet in length.

Roads, streets, and sidewalks shall be shown as the separation between curb faces, hard surface edges, travel paths, or shoulder lines, as the case may be. The drafting of road alignment, shall be especially carefully executed. Roads or regular alignment shall be plotted with straightedge and regular curves. Freehand or irregular curve drawing will be permitted only on meandering roads or trails or irregular alignments.
The surface type of all roads, drainage ditches, parking areas and other improved areas, except for private residential features, shall be identified and labeled by type, i.e., asphalt, concrete, brick, dirt, etc., as interpreted from field notes or aerial photographs.

Features which are interpreted from the photography as being under construction shall be labeled as such, and partly completed planimetric features in connection therewith shall be shown by dashed lines.
Any pattern of lines visible on the photographs, but which cannot be readily identified as definite features and shown by a standard symbol, will be located and shown on the map by fine dotted lines.

ACCURACY OF MAPS

All map accuracies specified herein shall apply to the individual stereo models that comprise the finished maps delivered by the consultant.

90% of all planimetric features shall be collected so that their position on the completed map shall be accurate to within at least one fiftieth (1/50) of an inch at final map scale, as determined by the test survey. None of the features tested shall be misplaced on the final map by more than one twenty-fifth (1/25) of an inch at final map scale.
The position of GNSS points and traverse points shall be mathematically correct in the design file.
90% percent of contour elevations generated from the DTM shall be accurate with respect to true elevation of 1/2 contour interval or better and the remaining 10% of such elevations shall not be in error of more than one contour interval. Contours generated in areas obscured by dense cover shall be dashed to indicate questionable accuracy.
90% percent of all spot elevations placed on the maps shall be accurate to within 1/4 contour interval, and the remaining 10% shall be accurate to within 1/2 contour interval.

CHAPTER 15: UTILITY SURVEYS

GENERAL

This chapter is to be used for all utility installation, improvement, relocation, and removal projects conducted within UDOT right-of-way. It shall be used by all Department employees, consultants, and utility owners performing utility surveys. It is their responsibility to adhere to all relevant processes, workflow, and provisions stated in this chapter. Utilities are facilities and networks used for generation and transmission or distribution of the following including but not limited to; electricity, telecommunication(e.g. atms, fiber, cable, internet transmission), gas, sewer, or water.

AS-BUILT SURVEY

In order to keep the Department's assets database current; a complete as-built must be submitted at the end of the project. This is essential for documenting the location and other important attributes of installed, abandoned, and discovered underground and above ground utility infrastructure. The as-built will be collected during the entire construction phase in order to capture all features on the project both above and below grade.

Standard UDOT Survey codes will be used on all department projects for as-built collection. If a code is needed that is not included in the standard survey codes it may be used, but the non-standard code must be noted, included in the UDOT Civil .XIN file with included feature definition, and assigned symbology.

Include the following utility survey information in the as-built:

- Existing utilities that are exposed below grade.
- Installed and abandoned utilities included in the design files
- Discovered utilities exposed during construction.
- Supplemental features as determined by the Engineer.

ACCURACY ATTRIBUTES

All collected features shall be assigned a positional accuracy level attribute. The accuracy level definitions are provided in Figure 15-1. Accuracy level requirements for all new installations will be at least Level 1. Specific circumstances (risk, practicalities, and costs) that may make it difficult to obtain Level 1 accuracy may be discussed with UDOT's representative. If UDOT agrees to consider accepting a lesser accuracy level the decision needs to be agreed upon and documented prior to conducting the survey. Datums, Projections, and Coordinate Systems will adhere to the requirements as set forth in this manual.

The positional accuracy levels defined in **Error! Reference source not found.** match up loosely with the following concepts:

- Level 1 is designed specifically to match QL-A as defined in the CI/ASCE 38 standard
- Level 2 is substantially identical to Level 1, but removes the close tolerance on vertical methods and thus can be generally achieved without the need for survey bench leveling.
- Level 3 is generally possible using GPS equipment and RTK methods.
- Level 4 can generally be achieved for X and Y data and is required of SUE providers designating utilities at QL-B on UDOT projects.
- Level 5 is generally achievable by post-processed mapping grade GPS equipment.

FIGURE 15-1-RELATIVE POSITIONAL ACCURACY REQUIREMENTS

Level	Positional Accuracy[1]	Applies to	Comment
1	±15 mm (±0.1 feet) Vertical ± 50 mm (±0.1 feet) Horizontal	Z data X and Y data	Coincides with requirements in CI/ASCE 38-02 standard for quality level A (QLA)
2	± 50 mm (±0.2 feet)	X, Y, and Z data	
3	± 150 mm (±0.5 feet)	X, Y, and Z data	
4	± 3000 mm (±1 foot)	X, Y, and Z data	
5	± 1000 mm (±3+ feet)	X, Y, and Z data	
6	± 1000 mm (±3+ feet)	X and Y	Positional accuracy of the X, Y, and Z data is indeterminate
9	Indeterminate		

[1]At the 95% confidence level, using the root-mean-square error (RMSE) in accordance with FGDC-STD-007.3-1998

APPLICATION OF SPATIAL ACCURACY

The positional accuracy of points measured in the field shall be assessed separately from the positional accuracy of derived features. The accuracy level of a measured point is often higher than that of a line segment between points.

COLLECTION OF FEATURE DATA

At the time of construction or at any time that an underground utility is subsequently exposed or visible and capable of measurement, the horizontal and vertical position and corresponding accuracy level shall be obtained and recorded as follows:

- For each distinct feature of the underground utility.
- For horizontal bends, vertical bends, and points of deflection.
- At specific points or intervals in accordance with the Data Collection Intervals Section.

DATA COLLECTION

Data collection intervals depend on the orientation and type of utility, site location, specific engineering requirements, and other requirements to meet the assigned point node and/or line segment accuracy levels defined above. Guidance for determining the data collection interval is provided below.

Effect of Horizontal or Vertical Curvature on Accuracy

As shown in Figure 15-2, when a lineal feature segment (e.g., cable or pipe) curves in either the horizontal or the vertical, a line string passed thru the collection of points will vary from the true location. The solid line represents the true location, while the dashed line indicates the line as determined from the discrete point collection and straight line linear interpolation.
To designate a specific accuracy level the error (A in Figure 15-2) due to chord offset must be less than the assigned accuracy level (Figure 15-1).

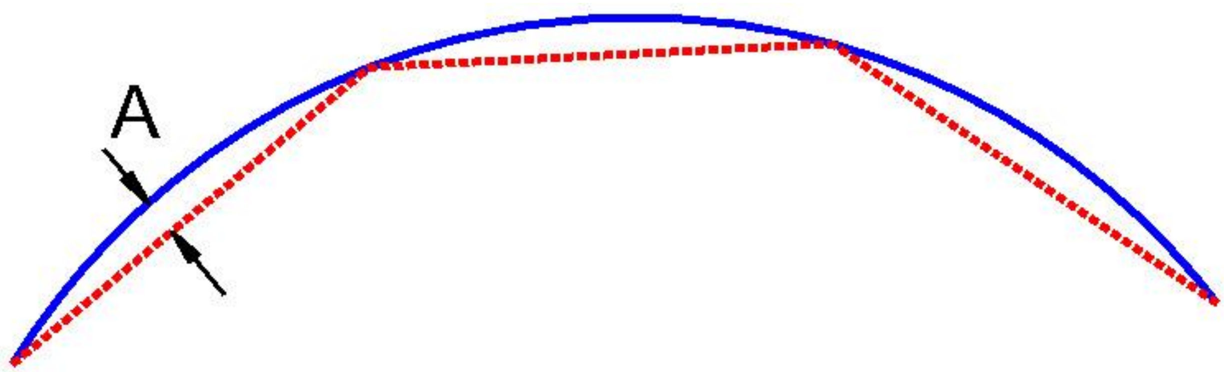


Figure 15-2 - Offset Error of Chorded Line String 1

Effect of Deflection on Accuracy

Figure 15-3 is a diagram illustrating how deflection combined with previously discussed curvature, can affect accuracy designation.

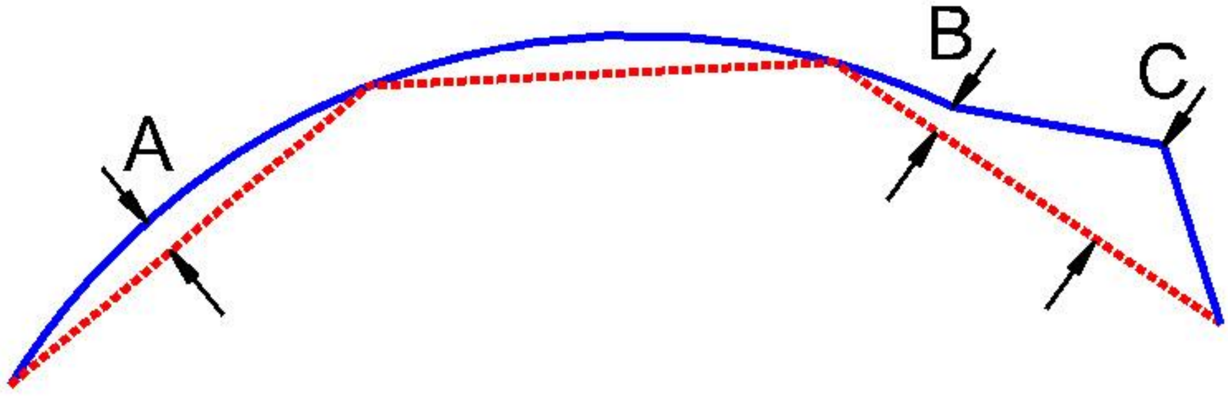


Figure 15-3 - Offset Error due to deflection

The offset error at A is the error due to curvature discussed in previous section. Errors at B and C in Figure 15-2 are due to deflection. These points of deflection introduce additional considerations for required point collection intervals. To designate the feature segment survey as meeting a specific accuracy level, additional points must be collected at B and C to ensure offset errors are less than the assigned accuracy level (Figure 15-1).
Points of deflection may occur in the horizontal or vertical planes, or both planes at a single point.

Necessity of a Segment by Segment Analysis

Using Figures 15-2 and 15-3 note the following:

- The effect of horizontal curvature may occur simultaneously with the effect of vertical curvature for any given segment length.
- Horizontal and vertical curvature may occur in segments between points of deflection.

Thus, consideration must be given to any linear feature in segments, determining points of deflection and segments which are curved.

Then for each segment a point collection interval is determined which will produce a modeled feature whose position compared to true position does not exceed the assigned accuracy level (Figure 15-1) at any point along the feature segment.

Computed Splines or Curves

While modern computing systems are fully capable of computing splines or curves through a collection of points, and this computed spline can match the actual location of the linear feature within the required error limits using fewer points, this process should not be used because:

1. Collected data is only truly valid at the collected observation points and thus the only valid comparisons are:
    - At those specific observation points
    - At measured offsets from the point string to the actual location

- A computed curve introduces additional problems during data transfer because the parameters of the computed curve would need to be transferred along with the modeled feature and the ASCE standard does not have a process for doing this currently.

ABOVEGROUND FEATURES AND WIRES

Rigid aboveground features are subject to the same positional accuracy requirements as underground infrastructure. The positional accuracy of suspended aerial cables and wires is variable due to environmental factors and therefore shall be classified as Level 9, except at the points where they are anchored to support structures such as poles. Collect sag vertical clearances with date, time, and temperature attributes.

Boxes, vaults, and enclosures

Collect information for boxes, vaults, and enclosures so that they can be accurately represented within the database. At a minimum, three (3) corners of a rectangular/square box will be collected along with a definition for the outside depth. It is preferred to collect all corners of the enclosure on the top and bottom. Lids and/or entry points will also be represented by a point collected in the center. All utility lines going into and out of the enclosure will also need to be collected so that their orientation is depicted correctly.

TRENCHLESS TECHNOLOGY

Where part or all of the installation of the underground utility has been achieved by trenchless technology methods, collect the utility features at points of exposure, accurately measuring and recording positions in order to meet the requirements of this section.

Any portion of the trenchless feature that is not directly measured shall be designated in accordance with ASCE 38 and Positional Accuracy Level 9.

Where the underground utility cannot be exposed or designated (e.g., when it passes below a structure or body of water) its position should be measured where the utility was last observed when it enters and when it exits the obscured area. The portion of utility that is obscured shall be clearly indicated that it has not been measured.

Discrete boring logs shall be collected along the trenchless alignment and processed to absolute Z referenced to the project survey control.

Rule of Thumb for Minimal Observation Frequency

The surveyor should assess the identified error situations which can arise for any installation and increase observation frequency sufficiently to mitigate risk of creating the framework for a distorted representation of the installation.

Survey observations should include:

- **All inflection points** (vertical and horizontal),
- **All joints** (noting that the collection point is at a joint and at maximum geometric deviations such as flairs for bell joints), and at **locations where facilities join or diverge**, such as at tees, “Y”s, splice joints, valves, etc.,
- **All feature nodes and point features**.

The observation frequencies must be sufficient so that the digital rendition yielded through the 3-D modeling application and based on the observation points, creates a virtual representation that is practically identical geometrically to the actual utility and spatially within the assigned accuracy level (a.k.a. error tolerance).

Beyond those observation criteria, the following are recommended as minimal observation frequencies for feature segments:

- Rigid Feature Segments (e.g., reinforced concrete pipe installed at fixed grades) - 20 feet intervals
- Flexible Feature Segments (e.g., direct bury fiber optic) – 10 feet intervals

UTILITY SURVEY DELIVERABLES

The survey report shall be accompanied by all field notes used in the survey or printouts or electronically recorded field notes. The survey shall be collected to Level 1 relative accuracies as defined in Figure 15-1.

The following files shall be included:

- Original Field Data
  - File describing the Basis of Survey Elements and Datum in accordance with Department Standards
  - File containing original field survey notes or raw field data when obtained with Data Collectors. The raw data in the native data collector format. (e.g. DC, RINEX, RW5, ASCII, or DAT) file format and log sheets must also be preserved for future retrieval.
- Cleaned up topographic as built survey in MicroStation DGN Format or other compatible format as approved by the Technology Advancement Engineer.
  - The topographic survey should be free of any code errors and all breaklines and features connected and not overlapping.
  - All features, linework, cells, and text need to be scaled based on UDOT Cadd Standards.
    - Any additional created cells need to be included with the deliverable in a MicroStation Cell Library.
    - The files must be named according to the UDOT Cadd Standards.

SUBSURFACE UTILITY ENGINEERING (SUE)

Subsurface Utility Engineering (SUE) services inherently require some surveying activities that fall under the purview of this manual.

The SUE Consultant must certify horizontal and vertical accuracies of utility locations within ± 0.1 foot when performing Locate Services, (Test Hole) Quality Level A. In order to obtain these accuracies on a project the surveyor shall tie the test holes to project control as defined in chapter 5 of this manual. These ties to project control shall conform to the minimum surveying standards and procedures as spelled out in this manual.

The SUE Consultant must certify horizontal accuracies of utility locations within ± 1 foot when performing Designating Services, Quality Level B. In order to obtain these accuracies on a project the surveyor shall tie the utility designation points to project control as defined in chapter 5 of this manual. These ties to project control shall conform to the minimum surveying standards and procedures as spelled out in this manual.

Coordinate with the Project Manager in conjunction with the Region Surveyor and the Project Surveyor/Consultant to obtain horizontal and vertical data from appropriate project control, or to request supplemental control in the vicinity where the subsurface utility engineering activities are planned.

Refer to the Department's General Engineering Services, Subsurface Utility Engineering (Discipline #21) consultant requirements, and CI/ASCE 38- current edition, Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data, for procedures to perform D, C, B and A quality level services to obtain horizontal and vertical data, including designating and locating subsurface utilities.

APPENDIX

STANDARD SPECIFICATIONS

See Standard Specification 01721 “Survey”

See Standard Specification 02896 “Right-Of-Way Markers and Boundary Survey"

REFERENCES

References:

Federal Geodetic Control Subcommittee, 1995, *Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems*, Version 4.1, 27 May 2004.

Federal Geographic Data Committee, *Part 1, Reporting Methodology, Geospatial Positioning Accuracy Standards*, FGDC-STD-0007.1-1998, Washington, D.C., 1998.

Federal Geographic Data Committee, *Part 2, Standards for Geodetic Networks, Geospatial Positioning Accuracy Standards*, FGDC-STD-007.2-1998: Washington, D.C., 1998.

Federal Geographic Data Committee, *Part 3., National Standard for Spatial Data Accuracy, Geospatial Positioning Accuracy Standards*, FGDC-STD-007.3-1998: Washington, D.C., 1998.

Federal Geographic Data Committee, *Part 4: National Standards for Spatial Data Accuracy, Standards for Architecture, Engineering, Construction (A/E/C) and Facilities Management*, FGDC-STD-007.4-2002, Washington, D.C., 2002

Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques (1989), Federal Geodetic Control Committee

Ghilani, C. D. and P. R. Wolf. 2014. *Elementary Surveying: An Introduction to Geomatics*. Prentice Hall Publishers, Upper Saddle River, NJ.

Guidelines for Establishing GPS-Derived Ellipsoid Heights (1997) NOAA Technical Manual NOS NGS-58, Zilkoski, et al.

Guidelines for Establishing GPS-Derived Orthometric Heights (2008) NOAA Technical Manual NOS NGS-59, Zilkoski, et al.

Bench Mark Reset Procedures, Smith, C.L., NGS, September 2010

U.S. Army Corps of Engineers, Engineer Manual *EM 1110-1-1002, Survey Markers and Monumentation*, 1 March 2012

Standards and Guidelines for Cadastral Surveys Using Global Positioning System Methods (2001), USDA Forest Service, Dept. of the Interior, Bureau of Land Management

Standards and Specifications for Geodetic Control Networks (1984), Federal Geodetic Control Committee

TM 11-D1, *Methods of Practice and Guidelines for Using Survey Grade GNSS to Establish Vertical Datum in the United States Geological Survey (2012)*, Rydlund, Paul H., and Densmore, Brenda K.

U.S. Army Corps of Engineers, Engineer Manual *EM 1110-1-1003, NAVSTAR Global Positioning System Surveying* , 28 February 2011

U.S. Army Corps of Engineers, Engineer Manual *EM 1110-1-1005, Control and Topographic Surveying*, 1 January 2007

User Guidelines for Single Base Real Time GNSS Positioning, Version 2.1(2011), William Henning, National Oceanic and Atmospheric Administration, National Geodetic Survey

USGS Global Positioning Application and Practice, United States Geological Survey (Website)

Andrew, Burfield, Helmer, Holtz, Maher, Marois, Ream & Tremba (California Land Surveyors Association and California Spatial Reference Center Joint Task Force), *GNSS Surveying Standards and Specifications*, Version 1.1, December 2014

Anderson, D'Onofrio, Helmer & Wheeler (California Geodetic Control Committee), *Specifications for Geodetic Control Networks Using High-Production GPS Surveying Techniques*, Version 2.0, July 1996

US Department of Transportation Federal Highway Administration, *Manual on Uniform Traffic Control Devices for Streets and Highways*, 2009 Edition, Including Revision 1 dated May 2012, and Revision 2 dated May 2012

California Department of Transportation, CALTRANS – SURVEYS MANUAL, 2006-2015

Texas Department of Transportation, TxDOT SURVEY MANUAL, Revised April 2011

Oregon Department of Transportation, CONSTRUCTION SURVEYING MANUAL FOR CONTRACTORS, February 1, 2014

Washington State Department of Transportation, HIGHWAY SURVEYING MANUAL, M 22-97, January 2005

Colorado Department of Transportation, CDOT SURVEY MANUAL, 2003-2010

UDOT STANDARD SURVEY CODES

Below are the UDOT Standard Survey Codes to be used on all topographic and as-built surveys. If a code is needed that is not included in the standard survey codes it may used, but must be noted in the deliverable package. It must also be included in the UDOT Civil .XIN file with included feature definition and assigned symbology.

--

ATMS

--

1 CLUSTER OF 4 CONDUITS	CCI
2 CLUSTERS OF 4 CONDUITS	CCII
2" CONDUIT	CTWO
3 CLUSTERS OF 4 CONDUITS	CCIII
3" CONDUIT	CTHR
4 CLUSTERS OF 4 CONDUITS	CCIV
4" CONDUIT	CFR
6" CONDUIT	CSIX
8" CONDUIT	CET
A PULL BOX	APB
A PULLBOX SPLICEPOINT	ASP
B PULL BOX	BPB
B PULLBOX SPLICEPOINT	BSP
CLOSE CIRCUIT TV CABINET	CCTV
CC TV/TRFC MONITORING CABINET	CCTMC
FULL CABINET	CCFC
C PULL BOX	CPB
C PULL BOX SPLICEPOINT	CSP
D PULL BOX	DPB
D PULL BOX SPLICEPOINT	DSP
RAMP METER CONTROL CABINET	RMC
TRFC MONITORING STATION CBNT	TMS
VMS CABINET	VMS
VAULT PULL BOX	VPB
VAULT SPLICE POINT	VSP

CABLE TV

CABLE TV LINE	CTL
CABLE TV PED	CTP
BURIED CABLE TV	BCTV
CABLE TV BOX	CTB

CONTROL CODES

BEGIN FIGURE	BF
CLOSE FIGURE	CLOSE
POINT OF CURVATURE	PC
POINT OF TANGENT	PT
DO NOT CONTOUR	DNC
RECTANGLE	RECT
CLOSE RECTANGLE	CLRECT
JOIN POINT	JPT
NON TANGENT CURVE	NT
DISTANCE	DIST
TEMPLATE	TMPL

CURB & GUTTER

CURB	C
CURB & GUTTER FACE	CF
CURB & GUTTER FLOW LINE	CFL
CURB & GUTTER LIP	LOC,LG
CURB & GUTTER TOP BACK	TBC
ROLLED GUTTER EDGE	RGE
ROLLED GUTTER FLOWLINE	RGF
DECORATIVE CURB	DC

--

DRAINAGE

--

DI WITH TRASHRACK	SDIT
DROP INLET	SDI
STORM DRAIN	SD
CHECK DAM	HCD
DRAINAGE BOX	HDB
CATCH BASIN	HCB
CLEAN-OUT BOX	COB

--

ELECTRICAL

--

BURIED ELECTRICAL CABLE	BCE
ELECTRIC JUNCTION BOX	EJB
ELECTRIC POWER POLE	EPP, POLE
ELECTRIC TRANSFORMER	ET
LIGHT POLE	LP
OVERHEAD POWER LINE	OPL
OVERHEAD WIRE	OHW
POLE GUY WIRE ANCHOR	GWA
POLE GUY WIRE	GW
POWER POLE STREET LIGHT	EPPS
JUNCTION BOX STREET LIGHT	EJBS
OUTDOOR DECORATIVE LIGHT	ODL
ELECTRICAL MANHOLE	ME

FENCE

FENCE	F
FENCE CHAIN LINK	FCL
FENCE DECORATIVE	FD
FENCE FIELD	FF
FENCE RAIL	FR
FENCE WIRE	FWR
FENCE WOOD	FW
FENCE WOOD POST	FWP
GATE POST	GA
FENCE VINYL	FV
FENCE DEER	FDR
DEER GATE	DRG

GAS

GAS METER	GM
GAS VALVE	GV
BURIED GAS LINE	BGL
GAS RELIEF VALVE	GRV
GAS SIGN	SNG
GAS MANHOLE	MG

SEWER

SEWER CLEANOUT BOX	SCO
SANITARY SEWER PIPE	PSS
BURIED SEWER	SBS
SANITARY SEWER MANHOLE	MS
STORM SEWER MANHOLE	MSS

IRRIGATION/WATER

WELL	WELL
SPRINKLER VALVE	SV
SPRINKLER	SPK
JUNCTION BOX IRRIGATION	JBI
WATER PUMP	WP
SCREW GATE	HSG
WIER GATE	HWG
HAND SLIDE GATE	HHG
FIRE HYDRANT	FH
WATER VALVE	WV
WATER METER	WM
BURIED WATER LINE	BWL
HOSE BIB	HB
SPRINKLER BOX	SBX
RISER	RSR
MONITORING WELL	WMW
WATER MANHOLE	MW
STORM SEWER MANHOLE	MSS
BURIED IRIGATION LINE	BIRR
IRRIGATION VALVE	IRRV

MANHOLES

MANHOLE	M
SANITARY SEWER MANHOLE	MS
STORM SEWER MANHOLE	MSS
TELEPHONE MANHOLE	MT
WATER MANHOLE	MW
GAS MANHOLE	MG
ELECTRICAL MANHOLE	ME
MANHOLE PETROLEUM	MP

PIPE

CORRUGATED METAL PIPE	CMP
PLASTIC PIPE	PPL
REINFORCED CONCRETE PIPE	RCP
STEEL PIPE	SP
ARCH PIPE	PA
CONCRETE CULVERT PIPE	CCP
IRRIGATION PIPE	IRP
CORRUGATED PLASTIC PIPE	CPP
SANITARY SEWER PIPE	PSS
BURIED SEWER	SBS

RAILROAD

RAILROAD CROSSING	RRX
RAILROAD GATE	RRG
RAILROAD SIGNAL	RRS
RAILROAD SIGNAL CTRL CABINET	RRCB
RAILROAD SWITCH	RRW
TOP OF RAIL	RTR
RAILROAD MISC	RRM
RAILROAD CROSSING SIGN	SRR
RAILROAD SIGN	RSG

ROAD

DELINEATOR	DEL
DRIVEWAY	DRV
EDGE OF ASPHALT	EA
EDGE OF CONCRETE	EC
EDGE OF DIRT	ED
EDGE OF GRAVEL	EG

GUARD RAIL	GR
ASPHALT DRIVEWAY	AD
CROWN LINE	RCL
CONCRETE DRIVEWAY	CD
GRAVEL DRIVEWAY	GD
EDGE OF GRASS	EOG
ATTENUATOR	ATT
SAND BARRELS	SBL
CULVERT MARKER	CMR

ROAD PAINT

CROSSWALK	CW
CROSSWALK SCHOOL	CWS
DOUBLE YELLOW	DY
SINGLE WHITE DOTTED	SWD
SINGLE WHITE LINE	SWL
SINGLE YELLOW LINE	SYL
SINGLE WHITE SKIP	SWS
SINGLE YELLOW SKIP	SYS
STOP BAR	SB
TURN ARROW LEFT	LTA
TURN ARROW RIGHT	RTA
YELLOW PERMISSIVE LEFT	YPL
YELLOW PERMISSIVE RIGHT	YPR
YELLOW BROKEN	YB
PAINT MESSAGE	PM
PED CROSSING BAR	PCB
STRIPE DBL YLW PERM	DYP
8" WHITE PAINT LINE	EPL
CATTLE GUARD	PCG
SHOULDER LINE	SH
BIKE MESSAGE	BK
BIKE STRIPING	BKS
STRAIGHT ARROW	SA

STRAIGHT RIGHT ARROW	SRA
STRAIGHT LEFT ARROW	SLA
STRAIGHT RIGHT/LEFT ARROW	SBA
MERGE ARROW	MA
INTERSTATE SHEILD	IS
HOV/FLEX LANE	PFL
RAILROAD CROSSING	PRX
SCHOOL MESSAGE	PS
HOV/FLEX LANE SYMBOL	FLS

SIGNALS

SIGNAL CONTROLLER	TSC
SIGNAL	TRS
SIGNAL POLE	TSP
SIGNAL POLE WITH LUMINAIRE	TSPL
SIGNAL JUNC BOX	TSJ
LOOP	SL
TRAFFIC SIGNAL CONDUIT/WIRE	TSW
PEDESTRIAN POLE	SPP

SIGNS

BUS SIGN	BUS
BUSINESS SIGN	BS
BILLBOARD/COMMERCIAL SIGN	SCA
GAS SIGN	SNG
NO PARKING SIGN	SNP
PEDESTRIAN CROSSING SIGN	SPX
RAILROAD CROSSING SIGN	SRR
SIGN	S
SPEED LIMIT SIGN	SSL
STOP SIGN	SS
STREET SIGN	SST

TRAFFIC SIGN	ST
TRAFFIC ISLAND SIGN	STI
WRONG WAY SIGN	SWW
ONE POST SIGN	SOP
TWO POST SIGN	STP
THREE POST SIGN	STHP
MILE MARKER SIGN	MM
DOUBLE DOWN SIGN	SDD
RAILROAD SIGN	RSG
MERGE	SM
YIELD	SY
SCHOOL CROSSING SIGN	SX
SCHOOL CROSSING AHEAD SIGN	SXA
STOP AHEAD	SSA
SIGN W/FLASHING LIGHTS	SFL
OBJECT MARKING SIGN	SOM
DEER CROSSING	SDX
VARIABLE MESSAGE SIGN	SVM
ROUTE MARKER	SRM
MULTI-POST SIGN	SMP
BIKE	SBK
SIGN POST	SGP
PETROLEUM SIGN	SPT
FIBER OPTIC SIGN	SFO
CULVERT MARKER	CMR

--

SURVEY

--

BENCH MARK	BM
BRASS CAP	BRC
CENTER LINE	CL
PRIMARY CONTROL POINT	PCP
SECONDARY CONTROL POINT	SCP
CONTROL POINT	CP
MONUMENT	MON
NAIL	NAIL
PROPERTY LINE/CORNER	PL
PROPERTY LINE PLUG	PLUG
QUARTER CORNER	QC
CENTER QUARTER CORNER	CQC
REBAR	RB
REBAR W/CAP	RWC
RIGHT OF WAY MARKER	RM
SECTION CORNER	SC
STAKE	STK
BOUNDARY LINE	BL
EASEMENT LINE	EL
CONTROL LINE	CCL
16TH CORNER	SXC
WITNESS CORNER	WC
REFERENCE MARKER	RFM
TIE POINT	TPN

--

TELEPHONE

--

BURIED TELEPHONE CABLE	BCT
TELEPHONE BOOTH	TB
TELEPHONE PEDESTAL	TP
TELEPHONE BOX	TBX
FIBER OPTIC CABLE	FOC

BURIED FIBER OPTIC CABLE	BCF
FIBER OPTIC BOX	FOB
FIBER OPTIC SIGN	SFO
TELEPHONE MANHOLE	MT

--

TOPOGRAPHIC

--

BREAKLINE	BKL
BOULDER	BDR
BOX CULVERT	BCU
BRIDGE DECK	BGD
BUILDING CORNER	BC
BUS BENCH	BB
EDGE OF SEEDING	ES
EDGE OF TOPSOIL	ETS
FLOW LINE	FL
FOOTING	FTG
MAIL BOX	MB
NATURAL GROUND	NG
OVERPASS COLUMN	OPC
SIDEWALK	SW
TOE OF SLOPE	TS
TOP OF ASPHALT	TOA
TOP OF CONCRETE	TC
TOP OF SLOPE	TOS
TREE	TR
WETLAND BOUNDARY	WET
TOP OF OIL	TO
DTM BOUNDARY	BD
PICNIC TABLE	TABLE
DRINKING FOUNTAIN	DRINK
TREE LINE	TL
FLAG POLE	FP
DITCH	D
DITCH LINED	DL

TOP OF DITCH	TD
DITCH CONCRETE LINED	DCL
DITCH ROCK LINED	RLD
INVERT ELEVATION	INV
SHRUBS	SHR
CONCRETE BARRIER EDGE	CB
CATTLE GUARD	CTG
ATTENUATOR CABLE	TAC
BOLLARD	BLD
SHRUB LINE	SHL
CABLE BARRIER	CBR
EXPOSED UTILITY	EU

--
WALL
--

WALL	W
BARRIER WALL	BW
HEADWALL	HW
NOISE WALL	NW
RETAINING WALL	RW
DECORATIVE WALL	DW
TOP OF WALL	TW

--
STRUCTURES
--

PARAPET WALL	PW
PARAPET WALL W/FENCE	PWF
CORE LOCATION	CH
WINGWALL	WW
SLOPE PROTECTION	SLP
BRIDGE DECK	BGD
EXPANSION JOINT	EJ
DIAPHRAGM	DF
APPROACH SLAB	AS

COLUMN	COL
TOP OF PARAPET	TOP
DECK DRAIN	DD
BOLT	B
BEAM SEAT	BST
STEEL BEAM	BSB
CONCRETE BEAM	BCB